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JOURNAL OF PALEONTOLOGY

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VARVES AND FORAMINIFERA OF A PORTION OF THE UPPER PUENTE FORMATION (UPPER MIOCENE), PUENTE, CALIFORNIA[1]

D. D. RIVEROLL AND B. C. JONES

ABSTRACT—A well core of thinly laminated shale representing 11.9 feet of stratigraphic interval from the Puente formation was studied to determine if the rhythmic bedding was due to annual cycles. A varve profile was made to illustrate the variations in thickness of each pair of laminae consisting of a grey inorganic layer and an overlying brown foraminiferal layer. The assemblages of foraminifers at 149 points in the core were recorded on a range chart with each assemblage opposite its correct point in the varve profile. The rhythmic occurrence of certain foraminiferal assemblages, the lack of foraminifers in the grey layers, the graded bedding in each couplet of laminae, and the cycles of couplet thickness corresponding to known climatic cycles all attest that the couplets of laminae are varves.

INTRODUCTION

GEOLOGISTS and paleontologists working with well cores of the laminated or "poker chip" Miocene shales of the Los Angeles Basin have for years pondered the origin and conditions of deposition of these grey and brown sediments. These rocks are extremely compacted and well indurated and, although they generally contain a rich and diverse fauna of benthonic and pelagic Foraminifera, the state of preservation of the microfossils is very poor. Laminations of usually non-foraminiferal grey silty sand or clay are interbedded with thin layers of organic dark brownish-grey silt and clay containing the crushed and flattened foraminifers. Both the barren grey and the organic brown laminae vary in thickness from less than 1/100 inch to several inches. Textures of both kinds of laminae vary considerably from one locality to another within the Los Angeles Basin.

The presence of varve-like structure in these fine-grained Miocene rocks of the Los Angeles Basin has been mentioned by several earlier workers. Reed (1928) in his account of the lithology of a thinly laminated siliceous shale cropping out at Malaga Cove, south of the town of Redondo, suggests that the rhythmic bedding may be due to the annual rainfall cycle. Hoots (1930) described the thinly laminated shales of the Modelo formation and mentioned that the thickness of the laminae varied from an average of 0.15 mm. for a couplet consisting of one opal band and one adjoining brown organic band or colorless carbonate band, to 4 mm. thickness for single laminae in the siltier bands. Bradley (1931) described the banding of alternate organic and inorganic

[1] Acknowledgment is made to the managements of The Texas Company and the Union Oil Company of California for permission to publish this paper.

laminae in the shales of the Modelo formation (upper Miocene) of Southern California, and attributed their origin to the pulsating annual plankton cycle. Gillette (1939) used the varves of the Los Angeles Basin, which he thought averaged about 220 to 250 to the foot, as evidence for a 25,500 year climatic cycle. Bramlette (1946) in describing the rhythmic bedding in the Monterey shales of California adopted the word "Rhythmite" to "designate the couplet of distinct sedimentary types of rock" consisting of a clastic layer and an overlying organic layer, when the mode of formation and time connotation of the couplet is uncertain. He concluded that the thinnest of these rhythmic beds or couplets of laminae, averaging 0.1 to 0.2 mm. in thickness, represent the annual cycle and are therefore varves.

This paper presents a study of the lithology and microfauna from a core 3½ inches in diameter of this type of upper Miocene laminated shale taken at a depth of 4230 to 4250 feet from The Texas Company's Puente No. 9-1 well, located in Section 5, T. 2 S., R. 10 W., San Bernardino base and meridian, near the town of Puente, Los Angeles County, California.

The authors wish to express their thanks to Dr. K. O. Emery of the University of Southern California for making the organic carbon tests of the core and to Dr. Orville Bandy, also of the University of Southern California, who offered helpful criticisms of the manuscript.

METHOD OF ANALYSIS

A grinding wheel was used to obtain a flat surface lengthwise of the core and to expose the alternating thin grey and brown laminations on a smooth plane. The thin laminae were counted and their stratigraphic thickness was measured at right angles to the bedding plane on this flat polished surface. Measurements within a tolerance of 1/100 inch for each laminae were started at the bottom of the core at 4250 feet and covered a stratigraphic interval of 11 feet 9 inches. The thickness of each grey, silty clay non-foraminiferal band and each organic foraminiferal grey-brown clay band was plotted on a natural scale columnar section. A total of 1640 grey and brown laminations were counted.

Each grey, silty lamina graded from the coarser grains at its base up to the finer lutite grains at the top. The overlying foraminiferal brown clay layer was usually of the same grain size as the top of the grey layer, the only distinction between the two being one of a sharply defined color change in the sediment. The crushed remains of the foraminifers and diatoms were invariably found in this upper brown clay layer or upper half of the couplet. The stratigraphic thickness of each pair of laminae, or couplet, i.e., one grey layer with its overlying brown layer, was taken from the natural scale columnar section mentioned above and plotted within a tolerance of 1/100 inch on the varve profile, figure 1.

Breaks or gaps in the core and intervals of non-laminated massive siltstone were also recorded on the varve profile, and the profile line was broken at these points.

To obtain the best results the examination of the foraminiferal content of this type of shale must be made directly on the surface of the rock exposed by splitting along the bedding planes. The assemblage of foraminifers thus exposed represents the total population at that particular time. If the core material is broken and prepared by the washing and screening technique, the majority of the crushed foraminifers are destroyed and the only ones recovered are those small or strong enough to withstand such rough treatment. The washing method of sample preparation will not recover, from this shale, an assemblage representative of the true population either in species or relative abundance. However, the crushed foraminifers exposed by splitting the cores are poorly preserved and usually flattened. Very rarely is an identifiable aperture seen. The micropaleontologist, when examining such a jumbled mass of flattened tests, is usually frustrated in his attempts to identify species or even genera.

There are two methods of foraminiferal biostratigraphic classification currently in use for the upper Miocene of the extended Los Angeles Basin. One method employs the group of stages (Delmontian, Mohnian, etc.) by R. M. Kleinpell (1938) in which stages are determined by identifying foraminifers recovered in washed samples. The other method of biostratigraphic classification

utilizes some sixty marker horizons grouped into larger division units lettered A, B, C, D, and E. Stratigraphic correlations based on this so-called "crushed foram" system were established by S. G. Wissler (1940). This system is based on identifying the crushed foraminifers in sediments directly under the microscope without recourse to preliminary washing.

Without giving a detailed technical explanation, it may be pointed out that the crushed Foraminifera system is essentially a classification in two dimensions, whereas the orthodox classification deals in three dimensions. The nomenclature and criteria of species identification is quite different in the two systems. These differences make intercorrelation of the two methods extremely difficult and are responsible for much of the confusion that exists concerning them.

Because of the unfamiliarity of many paleontologists with this "crushed system" identification, the writers attempted, as best they could, to translate these two-dimensional identifications into the orthodox classification.

To analyze and record the fauna in this core it was necessary to split the core along the bedding planes at intervals of ¼ inch to 1 inch by striking it sharply with a broad chisel-shaped hammer. This was done after the thickness of each couplet of laminae was measured. The thin platy, brown laminae usually broke clean, exposing the myriads of flattened foraminifers resting in the matrix of clay and brown organic matter, just as they were imprisoned by burial. One hundred and forty-nine breaks were made in the core in the 11-foot 9-inch stratigraphic interval, and the fauna at each break was recorded below the varve profile opposite the couplet or couplets from which it came (fig. 1). It must be kept in mind that the fauna came from the top brown organic layer of each couplet, whereas the thickness of the couplet on the varve profile consists of the combined thickness of the brown layer and its underlying, grey, non-foraminiferal layer.

FORAMINIFERA

Examination of the range chart and varve profile, figure 1, discloses three significant facts concerning the occurrence of Foraminifera in this core. First, two arenaceous species, *Haplophragmoides* sp. and *Reophax* sp., persist from the top to the bottom of the core. These species are found in few to abundant numbers in practically every couplet split for examination. Second, there is a cyclical recurrence of calcareous foraminifers at fairly regular intervals. The calcareous foraminifers appear to be more or less confined to couplets of peak thickness. The third significant fact is the marked variation in the calcareous assemblages in immediately adjacent couplets whose thickness may vary from 0.12 inch to 0.70 inch. This variation is apparent not only in species present but in their relative abundance as well. Several very thin adjacent couplets may contain dissimilar assemblages, as in the case of the six assemblages grouped approximately 10.3 feet stratigraphically above the base of the core. Two of the couplets concerned cover a stratigraphic interval of 0.13 inch and contain four distinct foraminiferal assemblages, two different assemblages occurring in the brown layer of each couplet.

Before discussing reasons for the cyclical recurrence of the variable calcareous faunas and the presence in the intervening intervals of arenaceous foraminifers only, it might be helpful to review certain aspects of the ecology of Foraminifera. The life cycle of Foraminifera is known to be influenced by external environmental factors which are in turn controlled in part by seasonal weather variations. Probably of paramount importance is the food supply. Within the northern hemisphere the seasonal variations in light intensity, temperature, winds and other factors, have a direct bearing on the amount of phytoplankton present in the sea at any given time. The photosynthetic organisms, a major source of food of the Foraminifera, are most abundant at times when the nutrient salt supply and the amount of sunlight are sufficient for their rapid reproduction. These two factors vary in time of intensity in different localities. For example, in the Gulf of California, Revelle (1950) reports coring laminated diatomaceous sediments composed of alternating layers of diatoms and terriginous detritus. He attributes this laminated structure to the fall and winter flow-

ering of diatoms caused by the upwelling of nutrient-rich bottom water. Strong northwest November winds move the nutrient depleted surface water down the Gulf, creating the upwelling currents.

In the vicinity of Plymouth Sound, England, Myers (1934) describes the annual pulsation in the amount of food available for the Foraminifera. Early spring in this locality is the time at which there is an abundance of nutrient salts present in the water, and this, along with the lengthening of sunlight hours, results in an outburst of photosynthetic organisms, chiefly diatoms. This increase in organisms results in a depletion of nutrient salts by June. The Foraminifera respond to this spring increase in food by adding new chambers and reproducing. There are several minor outbursts of diatoms during the summer and fall. As winter approaches, the decreasing sunlight and accompanying decrease in food brings on a period of dormancy in the Foraminifera.

Sedimentation taking place during this winter period of dormancy would bury the foraminiferal population and, if the layer of sediment were thick enough to constitute an impassable barrier, the foraminifers would smother and die. Repopulation of the area would, in this case, be accomplished by foraminifers deposited at, or near, the surface of the winter sediments. Of course, just how much sediment is required to smother and kill a population of benthonic foraminifers is unknown. As aptly stated by Earl H. Myers (personal communication): "The depth of sediment required to smother a foraminifer is comparable to that of a man who might first find himself buried in snow, then hailstones, then blocks of ice. He might escape from an appreciable depth of one, but not of the other. . . ." "To what extent foraminifers can extricate themselves after being buried in sediments of different densities and grain size has not been determined."

In the core of this investigation the foraminifers in most of the brown layers were probably smothered by the overlying grey layer during their winter dormancy. Support for this conclusion is that the grey laminae in all 820 couplets examined were barren of foraminiferal tests. Even the thickest of the grey layers such as the one approximately 6.75 feet stratigraphically above the base of the core, which is over 2 inches thick, is barren. It is difficult to conceive of a population of foraminifers working up through such a thick blanket of clay and silt (probably at least 4 inches thick before compaction) without some individuals dying and remaining within the bed. On the other hand, foraminifers might have worked up through the thinner grey layers (several hundredths of one inch thick) without leaving any tests in these layers.

Foraminifers transported in after the deposition of each grey layer, and/or any foraminifers able to extricate themselves from the thinner of the grey layers, repopulated the sediment surface in the spring. The overlying brown organic lamina accumulated throughout that part of the year when the phytoplankton and Foraminifera production was highest. The yearly cycle was completed when the foraminifers became dormant again and were buried by the next winter's grey layer of sediment.

Certain arenaceous foraminifers are known to tolerate euxinic conditions better than the calcareous genera found in this core. This fact, and the fact that the peaks of calcareous Foraminifera abundance in the core correspond to peaks of thickness of the grey layers, strongly suggest that the calcareous Foraminifera were periodically introduced into an environment unsuited to them and in which they quickly perished, while the arenaceous Foraminifera continued to thrive. It may well be that the foraminifers of the brown layers were killed by such conditions even before the burial by the light grey layer. Such an hypothesis postulates a deep sill creating a local basin whose water in depth became increasingly stagnant. Seasonal shifts in winds and currents might overturn this water killing the foraminiferal population prior to burial by the light grey layer. Repopulation could be accomplished after the clearing of this water by currents which could sweep in new hordes from a healthy foraminiferal hinterland.

The marked variation in the calcareous assemblages in adjacent couplets is probably due to random sorting of the transported fauna or to variations in the fauna at the source locality, as well as to the effects of natural selection working on a

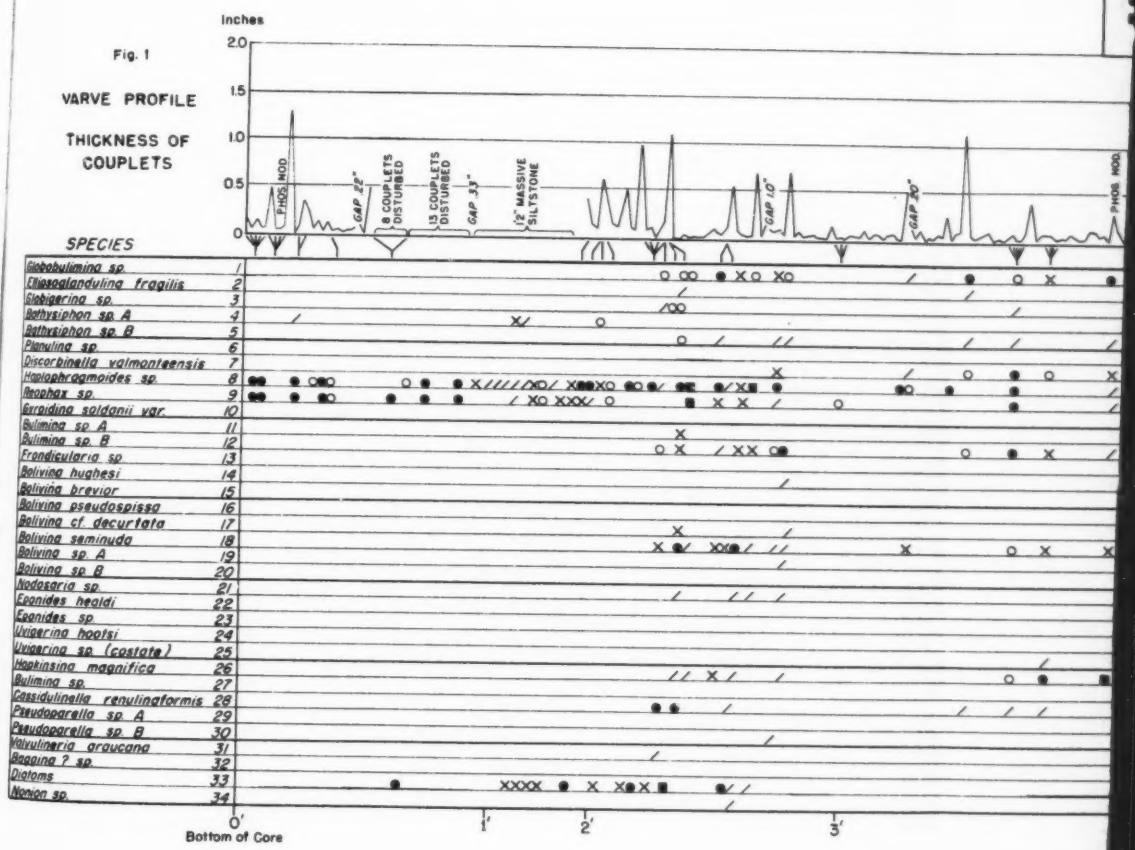


Fig. 1

VARVE PROFILE

THICKNESS OF COUPLETS

Fig. 2

THICKNESS OF BROWN LAYERS

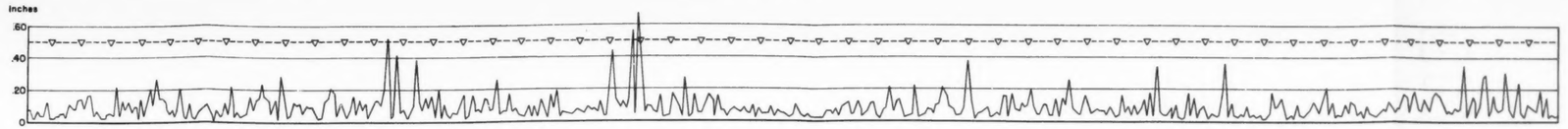
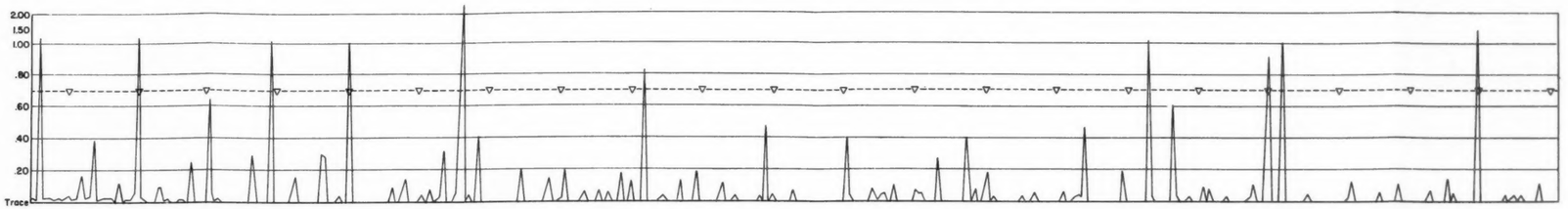


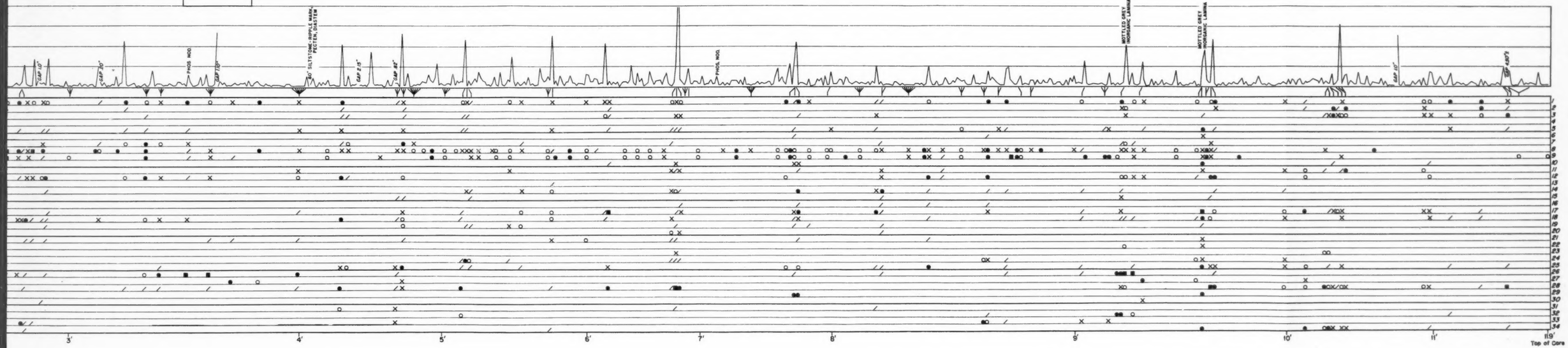
Fig. 3

THICKNESS OF GREY LAYERS



LEGEND

/ Rare
X Few
O Common
● Abundant
■ Very abundant



population struggling to survive in an unfriendly environment.

RATE OF DEPOSITION

The lithology of this core does not exhibit any characteristics of very slowly deposited sediments. During times of slow deposition, the surface of the sediments remains in contact with the overlying water for long periods. The activity of bacteria and other microorganisms, as well as benthonic scavengers and mud feeders, results in a depletion of the organic matter originally contained in the sediment. The core examined is high in organic matter. Organic carbon tests of both the grey and brown layers, performed by Dr. K. O. Emery of the University of Southern California, reveal an organic carbon content of 0.64 per cent in the grey layers and of 4.74 per cent in the brown layers.

To determine the total organic matter content, Emery uses the 1.7 ratio of total organic matter to organic carbon that is commonly accepted for soil humus. An 8.1 per cent computed total organic matter content of the brown layers reflects the richly organic state of the sediment and indicates that little oxidation took place subsequent to deposition. In fact, this high amount of organic matter is found only in recent sediments from basins in which almost reducing conditions prevail in the bottom sediments. The laminated silts and clays of this core were most likely deposited fairly rapidly, the organic matter in them being preserved by fast burial.

Further, the laminations are well preserved and show no signs of being disturbed by benthonic scavengers or burrowers. No faecal pellets or other remains of burrowers were observed in any of the laminae. Rare shells of *Delectopecten pedroanus*, a mud pecten, were the only megafossil remains found. No glauconite, a mineral sometimes associated with slowly deposited sediments, was found. All evidence points to fairly rapid deposition.

The unbroken 6-foot interval (see fig. 1) from approximately 4.5 feet stratigraphically above the base of core to about 10.5 feet above the base contains 510 couplets. If each couplet is one year's accumulation, the rate of deposition is 6 feet of compacted

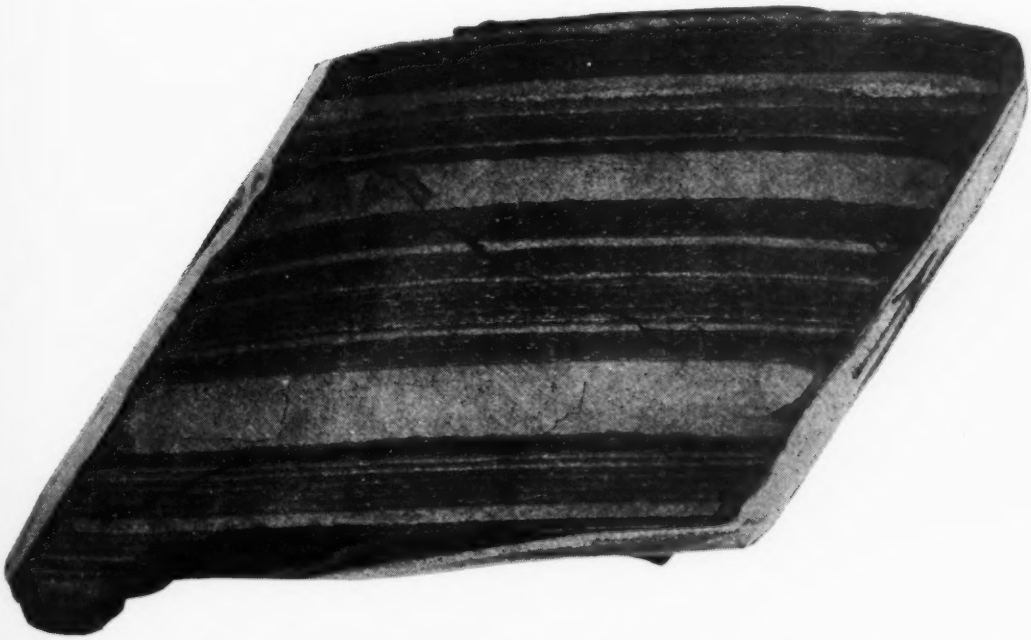


FIG. 4—Section of the core illustrating the inorganic layers (light grey) and the organic foraminiferal layers (dark grey). Small white specks within the dark layers are crushed foraminifers. Scale: approximately actual size. Arrow indicates top of core. Photo by Kenton D. Breidenthal.

FIG. 5—Photomicrograph of thin section showing graded bedding within light grey inorganic lamina. Elongated white spots in dark organic lamina are crushed foraminifers. Small angular grains scattered throughout organic lamina are probably quartz. Two large spots, one hexagonal, at top of graded bed are probably phosphorite nodules. 20×. Photo by William A. Sokol. Arrow indicates top of core.

sediments deposited in 510 years, or an average of .141 inch per year. The amount of compaction of the sediment may be roughly estimated by observing the crushed state of the Foraminifera. The thinner, more fragile Foraminifera are flattened to at least one-fifth their original thickness. Foraminifera such as *Ellipsoglandulina* and *Globobulimina*, which are almost round in cross section when living, are found in this core as thin impressions. (See crushed Foraminifera in photomicrographs of thin section, figs. 5, 6, 7, 8.) Of course, this is not conclusive evidence that the sediments have been compacted to one-fifth their original thickness, but is mentioned only to show the order of the compaction.

GRADED BEDDING

Graded bedding was observed in every couplet examined. The grain size graded from silty or very fine sandy clay at the base of each couplet up to lutite and brown organic matter at the top. Random mineral grains of silt size are scattered throughout the capping brown laminae, but the majority of silt size grains are found in the basal portion of each grey lamina as shown in the

photomicrographs of thin sections. The boundary between the top of the grey lamina and the base of its capping brown lamina is defined more by a change in color than by a sharp grain size change. Mechanical grain size analysis of the thickest grey layer (6.75 feet stratigraphically above base of core) showed this bed to be graded. Samples weighing 10 grams each were taken from the bottom third, middle third, and top third of this 2 inch thick grey layer. One hundred per cent of the material from middle and upper third samples passed through the 200 mesh screen (1/13 mm.) and consisted of silt and clay aggregates. The bottom third sample had the following composition by weight:

PER CENT BY WEIGHT	TYLER STANDARD SCREENS	
82.6	−200	mesh (silt and clay)
15.6	−150 +200	mesh (very fine sand)
.1	−115 +150	mesh (very fine sand)
.05	− 60 +115	mesh (fine sand)
.1	+ 60	mesh (medium sand)

The grading of the grain size from coarsest at the base of each couplet up to fine at the top could be caused by the action of one or several transporting mediums. Fraser (1929) found graded varves could be pro-

FIG. *6*—Photomicrograph of thin section showing same graded bed as in figure *5*, but in greater detail. 70×. Photo by Earl Pampeyan. Arrow indicates top of core.

FIG. 7—Detail of graded bedding in same light grey inorganic lamina illustrated in figures 5 and 6. 30×. Photo by Earl Pampeyan. Arrow indicates top of core.

duced in the laboratory when unflocculated clay was permitted to settle in fresh water slightly above the freezing point but only faint laminations developed when unflocculated clay was settled in fresh water at 20°C. In water with one-eighth the salinity of normal sea water, practically a massive clay was formed due to flocculation of the clay particles. Fraser demonstrated that the velocity of fall of particles smaller than 0.5 mm. in diameter decreases with sinking temperature until a minimum is reached at 0°C. As the size of the particle decreases, its velocity of fall is decreased proportionately to the lowering of the temperature of the water. However, the graded varves of this core were deposited in a marine environment, and though the temperature and salinity of the water can only be speculated upon, it does not seem likely (assuming the flocculation of clay in sea water) that the varved structure could be due to the same sedimentary process as Fraser believes is responsible for the graded varves of fresh water pro-glacial lakes. On the other hand, if all the clay in the subject varves flocculated and settled at the same velocity as the coarser silt grains an ungraded bed would have developed. Such is not the case, as microscopic examination disclosed graded bedding in every varve that was split for microfaunal determination. Thin sections from several intervals show graded bedding in even the thinnest laminae.

Kuenen and Migliorini (1950) reviewed the many possible causes of graded bedding and demonstrated that graded beds could be artificially produced by turbidity currents of high density. In the Puente core a differential settling rate of the particles could

be invoked as a possible cause of the graded bedding. However, certain objections might be raised to this explanation except as it applies to the very thinnest of the inorganic laminae which are no more than several silt grains thick. Examination by the writers of thousands of well cores from the upper Miocene of Los Angeles Basin has revealed the almost basin-wide extent or distribution of this varved structure for at least a part of the stratigraphic column. Within rather narrow limits the grain size of these varves is uniform throughout the whole Los Angeles Basin at the time-stratigraphic horizon represented by this core. If the differential settling rate of different sized particles is solely responsible for the graded bedding of these varves, then it must be assumed that the detritus was carried by currents throughout the whole basin to settle slowly and evenly through the water. The grain size analysis and thin sections, however, show that clay particles are found in the base of each varve as well as toward the top, the silt particles being most abundant near the base. If clay flocculates in normal sea water and sinks as rapidly as silt, then the silt particles should be distributed more or less evenly throughout each varve. If clay does not flocculate and sinks as slowly in sea

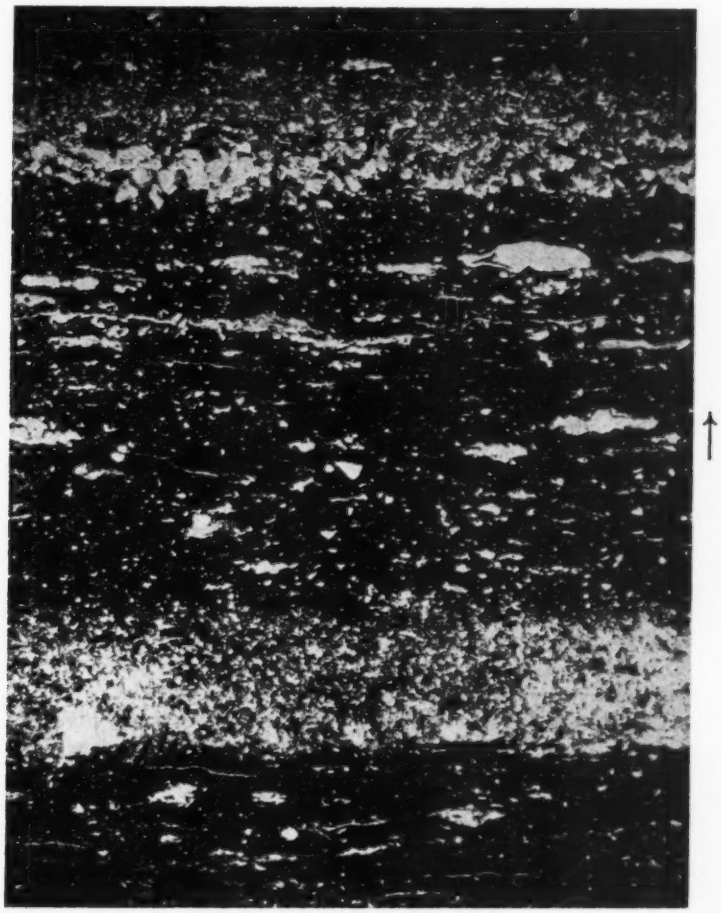


FIG. 8—Photomicrograph of thin section illustrating one complete couplet or pair of laminae. The couplet consists of the light grey layer at the bottom of the photo and the overlying dark organic layer with crushed foraminifers (elongated white spots). Grey layer of the next couplet above may be seen at the top of the photo. 20×. Photo by Earl Pampeyan. Arrow indicates top of core.

water as is implied, by the application of the formulas of Stokes and Oseen (quartz sphere 0.001 mm. diameter, clay size, in distilled water at 20°C., sinks 7.77 cm. in one day), and there is every reason to believe that a clay particle being irregular and not spherical in shape would sink slower in relatively dense sea water, then the clay should be confined entirely to the upper portion of each varve and only the silt grains would be found in the lower portion. Even at the rate 7.77 cm. per day settling rate, a clay particle would sink only 28.10 meters in one year. Clay particles sinking at this slow rate through as little as 28 meters of water might not reach the bottom in one year due to turbulent motion of currents acting upon the particles.

Some mode of transportation and deposition of sediments in addition to random current distribution and differential settling rate of individual grains was probably responsible for the graded bedding in the varves of the Puente core. Bell (1942) described and illustrated (photos by Manley Natland) overflows of muddy water at the mouths of rivers where the less dense sediment-laden fresh water overflowed the more dense sea water. He believes that mixing of of the muddy overflow and the clear sea water takes place at the interface and that clouds of turbid water created by this mixing would be dense enough to sink to a lower level or to the sea bottom. The turbid mass of dense water would spread out upon reaching either the bottom or a depth at which the water is colder and denser though clear, and would then flow as a turbidity current down any slope in the first case, or spread out as an interflow in the latter case, to deposit its sediment in a vertically and laterally graded bed. By such a mechanism, fine clay and silt particles could be carried together to the bottom quicker than by differential settling and dispersal of individual grains. The relatively fine fractions involved could result in the formation of a turbid layer of fairly low density, and this layer might have been added to by each storm until it was dense enough to flow slowly down the submarine slope and out into the basin.

Cores from other wells in the eastern part of the Los Angeles Basin, at the approximate time-stratigraphic equivalent of the Puente core, demonstrate that fine-grained, graded, varved, platy shales grade laterally into coarser grained, roughly graded, sandy shales with some structural evidence of current bedding. This seems to indicate deposition by turbidity currents of high density that may have originated by subseasonal freshets or storm turbulence and/or accompanying slumps of sediments. This type of turbidity current, and the type referred to above as probably responsible for the graded varves of the Puente core, undoubtedly mixed, overlapped one another, and resulted in mixed sections of true varved and pseudovarved sediments. Sediments deposited by this means, even far from shore in fairly deep water, could reflect the annual weather and rainfall cycle and also the annual cycles of the phytoplankton and Foraminifera.

CYCLES

Figures 2 and 3 are profiles of the brown and grey layers, respectively, and were obtained by breaking down the original varve profile into its component parts. A portion at each end was discarded because of known multiple breaks resulting in loss of sequence. No claims will be made here to any sweeping generalization concerning specific cycles of sedimentation for the Los Angeles area. The few couplets measured at this one station would be completely inadequate for such a study, nor is that the purpose of this paper. The authors do present these two profiles with the belief that they show good evidence of rhythmic phenomena which cannot be accidental.

Figure 3 is a profile of the barren grey layers only. Superimposed is a dashed line with checks set at a rigid 22.8 year cycle. This double sunspot cycle has been reported by many workers investigating weather rhythms. Other cycles are present, especially one at approximately a 7.5 year interval. This last has been widely reported in weather rhythms, tree rings, and varve analyses.

Figure 2 is a profile of the organic brown layers only. Here the rhythm is very complex and there is apparent interference between several cycles. The reduced scale of the plot does not permit a multiple framework of rigid cycles for comparison. In addi-

tion to a good cycle of nearly 8 years there appears to be a rather strong one of 9.6 years which is shown by the dashed line and checks. Ellsworth Huntington (1945) regards a 9⅔ year rhythm as a biological cycle and reports such a cycle in the population of the Canadian lynx and salmon. It is also a recurrent rhythm in atmospheric ozone. It is not too surprising to find such a rhythm appearing in the highly organic brown layers.

Errors in measurement of obscure varves and mechanical breakage in the core probably cause some cycle disagreement. Even so, the agreement that is present would seem definitely beyond that of pure chance. Such agreement constitutes direct evidence testifying to the yearly character of the varves.

CONCLUSION

The writers believe that the lower grey, silty clay part of each couplet represents the winter accumulation derived from sediments stirred up by waves or currents and the detritus carried to the sea by rivers. The upper brown layer of each couplet is believed to be the organic deposit of spring and summer, together with random fine clay particles that rained down slowly on to the bottom or settled last from a turbidity current as it came to rest. The rhythmic occurrence of certain foraminiferal assemblages, the lack of foraminifers in the grey layers, the graded bedding in each couplet of laminae, and the cycles of couplet thickness corresponding to known climatic cycles all attest that the laminae of the Puente core are varves.

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ECOLOGIC ASPECTS AND STRATIGRAPHIC SIGNIFICANCE OF THE FORAMINIFER *CYCLAMMINA CANCELLATA* BRADY

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ABSTRACT—A critical examination of oceanographic data shows that *Cyclammina cancellata* Brady has worldwide distribution in modern seas, and, like all other known species of the genus *Cyclammina*, is most abundant in cool waters below continental shelf depths. The species also has widespread distribution in Tertiary rocks, where its presence in conjunction with other criteria suggests an open marine depositional environment at bathyal or near bathyal depths.

INTRODUCTION

THE question of the depositional environment of *Cyclammina cancellata* Brady has often been posed by its frequent and widespread occurrence in rocks of Tertiary, particularly Miocene, age. Its association in varied frequencies with other benthics in some rocks, with abundant planktonic Foraminifera in other sediments, and its predominance almost to the exclusion of other Foraminifera in still other samples have warranted investigation into the habitat of living representatives of this species. Fossil specimens almost the world over are strikingly similar to Brady's types in size, shape, internal structure, texture, and even coloration. This paper is intended to relate ecologic factors where Recent specimens have been collected by the various oceanographic expeditions to the Tertiary depositional environment of the fossils.

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RECENT DISTRIBUTION

Tests of *Cyclammina cancellata* Brady have been collected off the continental shelf of nearly every major land mass of the world (see figs. 1 to 10). This worldwide distribution is recorded by over 110 oceanographic stations in both eastern and western hemispheres from Greenland to Antarctica (tables 1 to 5).

Depth range.—Although Recent forms appear to be largely confined to water depths exceeding those which obtain over the continental shelf, soundings at the numerous stations yielding specimens of this foraminifer indicate a high tolerance of the species for water depth. The shallowest depth recorded (Norman, 1876) is 114 meters at a point off the southwestern coast of Greenland (fig. 1). Another unusually shallow station is recorded off the coast of Nova Scotia (fig. 2) in 164 meters of water (Cushman, 1920). The only other stations at which the water is possibly of less than continental slope depth are off the eastern coast of Japan (196 meters, fig. 3), as described by Asano (personal communication), and in the Strait of Magellan (fig. 4). Brady (1884) records a depth of "80 to 280" meters for the latter locality. All other stations yielding *C. cancellata* are located seaward from the edge of the continental shelf or in water deeper than 200 meters.

The greatest depth from which the species has been reported is 5800 meters. Brady (1884) locates this station north of the Hawaiian Islands (fig. 5). The next deepest station (5696 meters) is also in the North Pacific Ocean (fig. 5). It lies north of the latter locality and just south of the Alaskan Peninsula (Cushman, 1910). Another unusually deep station (3980 meters) is described by Brady (1884) in the South Atlantic Ocean midway between Brazil and southwest Africa (fig. 6). The deepest

FIG. 1—*C. cancellata* stations in the Greenland-Ireland region of the North Atlantic.

stations in the South Pacific (3928 and 3632 meters) are reported by Heron-Allen and Earland (1922) off Antarctica (fig. 7). The deepest *C. cancellata* stations in the Gulf of Mexico (2660 and 2362 meters) are recorded by Goës (1896) southeast of the mouth of the Mississippi River (fig. 2). All other stations in the Gulf of Mexico from which *C. cancellata* has been identified are between 338 and 1460 meters in depth. In the Caribbean Sea, the shallowest reported occurrence of the species is 798 meters, and the deepest is 2690 meters (Cushman, 1920). The occurrence of *C. cancellata* at a *Valorous* station (Norman, 1876) is interesting from the standpoint of location rather than depth (1380 meters). This station is southeast of the southern tip of Greenland in the open Atlantic midway between Labrador and Eire (fig. 1).

Temperature range.—It is unfortunate that bottom temperature data are lacking for about half of the stations at which specimens of *C. cancellata* have been collected. It is believed, however, that sufficient information is available for significant conclusions.

The seven highest bottom temperatures recorded at *C. cancellata* stations have been taken in the North Pacific. The warmest of these, a Soyo-maru station off Japan (fig. 3), is 12.1°C. and has been described by Asano (personal communication). Only two other stations, also in the North Pacific, approach so high a temperature. Both gave readings of 11.6°C. (Cushman, 1910, and 1921).

Five stations had bottom temperatures less than 2.0°C. The two lowest, 1.2° and 1.77°C., are, as would be expected, from the two deepest stations. These are also in the North Pacific Ocean (Brady, 1884, and Cushman, 1910). A reading of 1.8°C. was

TABLE 1.—*C. cancellata* STATIONS IN THE SOUTH PACIFIC OCEAN, THE MEDITERRANEAN SEA, AND THE ARABIAN SEA

Station No. (of Authors)	Latitude	Longitude	Depth (M.)	Temp. (C.)	Character of Bottom	Reference
		SOUTH PACIFIC OCEAN				
2784	48 41 00 S.	74 24 00 W.	388	—	—	Flint, 1897
H.A. & E. 18	66 38 00 S.	178 47 00 W.	3928	—	Br. M.	Heron-Allen & Earland, 1922
H.A. & E. 23	69 08 8 S.	178 12 7 W.	3632	—	Br. M.	Heron-Allen & Earland, 1922
H.A. & E. 29	69 29 5 S.	162 49 4 E.	1902	—	Gy. Br. M.	Heron-Allen & Earland, 1922
308	50 10 00 S.	74 42 00 W.	350	—	M.	Brady, 1884
310	51 30 00 S.	74 03 00 W.	800	7.9	M.	Brady, 1884
309	50 56 00 S.	74 15 00 W.	80 to 280	—	M.	Brady, 1884
218	2 33 00 S.	144 04 00 E.	2140	2.1	Glob. Oz.	Brady, 1884
311	52 50 00 S.	73 53 00 W.	490	7.7	M.	Brady, 1884
D5630	0 56 30 S.	128 05 00 E.	1138	—	Co. S., M.	Cushman, 1921
D5650	4 53 45 S.	121 29 00 E.	1080	4.5	Gn. M.	Cushman, 1921
168	40 28 00 S.	177 43 00 E.	2200	—	—	Brady, 1879
		MEDITERRANEAN SEA				
Several stations off eastern coast of Sicily			300–1500	—	—	Silvestri, 1893
		ARABIAN SEA				
6	15 30 04 N. to 8 21 03 N.	74 52 05 E. to 71 09 03 E.	+2476	+2.07	Br. Glob. Oz.	Chapman, 1895

Bk.	Black	Crs.	Coarse	Lt.	Light	Rd.	Red
Br.	Brown	Fne.	Fine	M.	Mud	S.	Sand
Brk.	Broken	For.	Foraminifera	Oz.	Ooze	Sh.	Shells
Bu.	Buff	Glob.	Globigerina	P.	Pebbles	Vol.	Volcanic
C.	Clay	Gn.	Green	Ptr.	Pteropod	Yl.	Yellow
Co.	Coral	Gy.	Gray	R.	Rock		

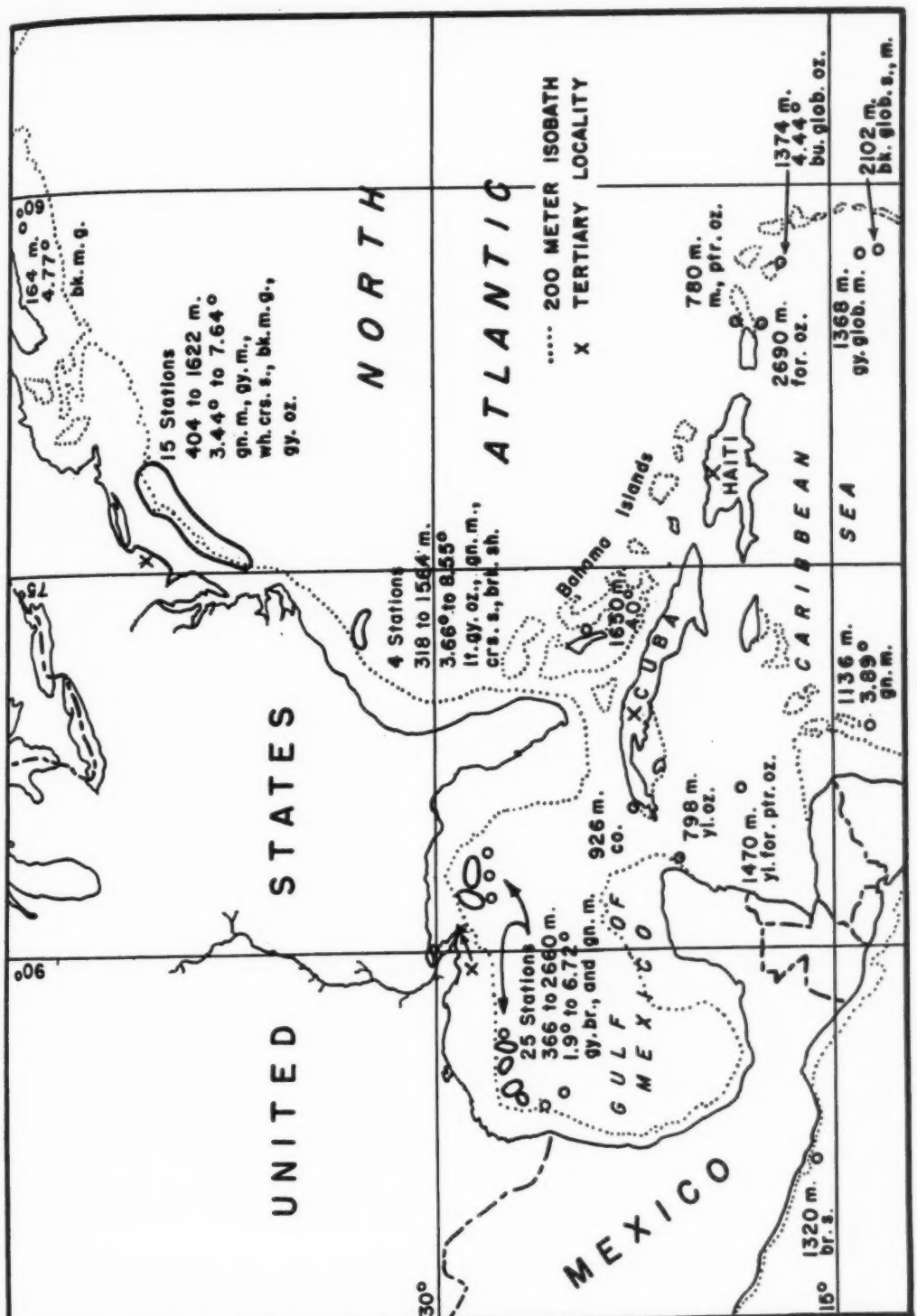

FIG. 2—Distribution of Recent and Tertiary *C. cancellata* in the Caribbean, Gulf of Mexico, and part of the North Atlantic region.

recorded at Brady's (1884) deep station in the South Atlantic Ocean (fig. 6). A bottom temperature of 1.9°C. was recorded at two stations in the Gulf of Mexico (Phleger, 1951).

As seen here, the two temperature extremes recorded in the literature are 1.2°C. and 12.1°C., while the bulk of available bottom temperatures falls between these extremes.

Associated Foraminifera.—Other Foraminifera have been collected with *C. cancellata* in Recent samples in varying numbers. A dredging off Japan in 196 meters of water (fig. 3) has obtained it in abundance without other species in association (personal communication, K. Asano). Many other collections, however, contain a complex assemblage in which numerous genera are represented.

Foraminiferal tests most often reported in the literature in association with *C. cancellata* are those of the pelagics. Quantitatively, this group certainly appears to dominate most of the Recent samples in which *C. cancellata* has been found. Although such an association is properly a thanatocoenotic one, an abundance of pelagic skeletons, whose living community was by and large the overlying waters, indicates a preference of the entire assemblage for undiluted sea water. This assumption is made on recent evidence by Parker (1948).

It would also be well to keep the possibility in mind that all benthic Foraminifera collected with *C. cancellata* may not have coexisted in precisely the same environment. New data on conditions in the present oceans show that "even in the abyssal depths of the ocean far from shore, irregularities of bottom topography exercise a profound control on the distribution of sediments" (Revelle, 1951). This should also be true of the dispersal of foraminiferal tests.

Certain benthic species have been repeatedly collected in *C. cancellata* dredgings,

TABLE 2.—*C. cancellata* STATIONS IN THE CARIBBEAN SEA AND THE SOUTH ATLANTIC OCEAN

Station No. (of Authors)	Latitude	Longitude	Depth (M.)	Temp. (C.)	Character of Bottom	Reference
			CARIBBEAN SEA			
D2172	38 01 15 N.	73 44 00 W.	1136	3.89	Gn. M.	Cushman, 1920
D2355	20 56 48 N.	86 27 00 W.	798	—	Yl. Oz.	Cushman, 1920
D2751	16 54 00 N.	63 12 00 W.	1374	4.44	Bu. Glob. Oz.	Cushman, 1920
H58	17 45 20 N.	65 35 35 W.	2690	—	For. Oz.	Cushman, 1920
H405	18 43 00 N.	83 36 45 W.	1470	—	Yl. For. Ptr. Oz.	Cushman, 1920
H80	13 56 00 N.	63 00 00 W.	1368	—	Gy. Glob. M.	Goës, 1896
H82	13 29 00 N.	62 42 00 W.	2102	—	Bk. Glob. S., M.	Goës, 1896
			SOUTH ATLANTIC OCEAN			
D2760	12 07 00 S.	37 17 00 W.	2038	4.16	Br. Co.	Cushman, 1920
D2761	15 39 00 S.	38 32 54 W.	1636	3.89	Ptr. Oz.	Cushman, 1920
D228	53 33 00 S.	61 49 30 W.	660	—	—	Heron-Allen & Earland, 1932
WS76	51 00 00 S.	62 02 30 W.	207	—	—	Heron-Allen & Earland, 1932
WS99	49 42 00 S.	59 14 30 W.	251	—	—	Heron-Allen & Earland, 1932
WS215	47 37 00 S.	60 50 00 W.	219	—	—	Heron-Allen & Earland, 1932
WS245	52 36 00 S.	63 40 00 W.	304	—	—	Heron-Allen & Earland, 1932
WS408	53 50 00 S.	62 10 00 W.	454	—	—	Heron-Allen & Earland, 1932
WS433	51 44 00 S.	56 23 00 W.	1035	—	—	Heron-Allen & Earland, 1932
120	8 37 00 S.	34 28 00 W.	1350	—	Rd. M.	Brady, 1884
338	21 15 00 S.	14 02 00 W.	3980	1.8	Glob. Oz.	Brady, 1884

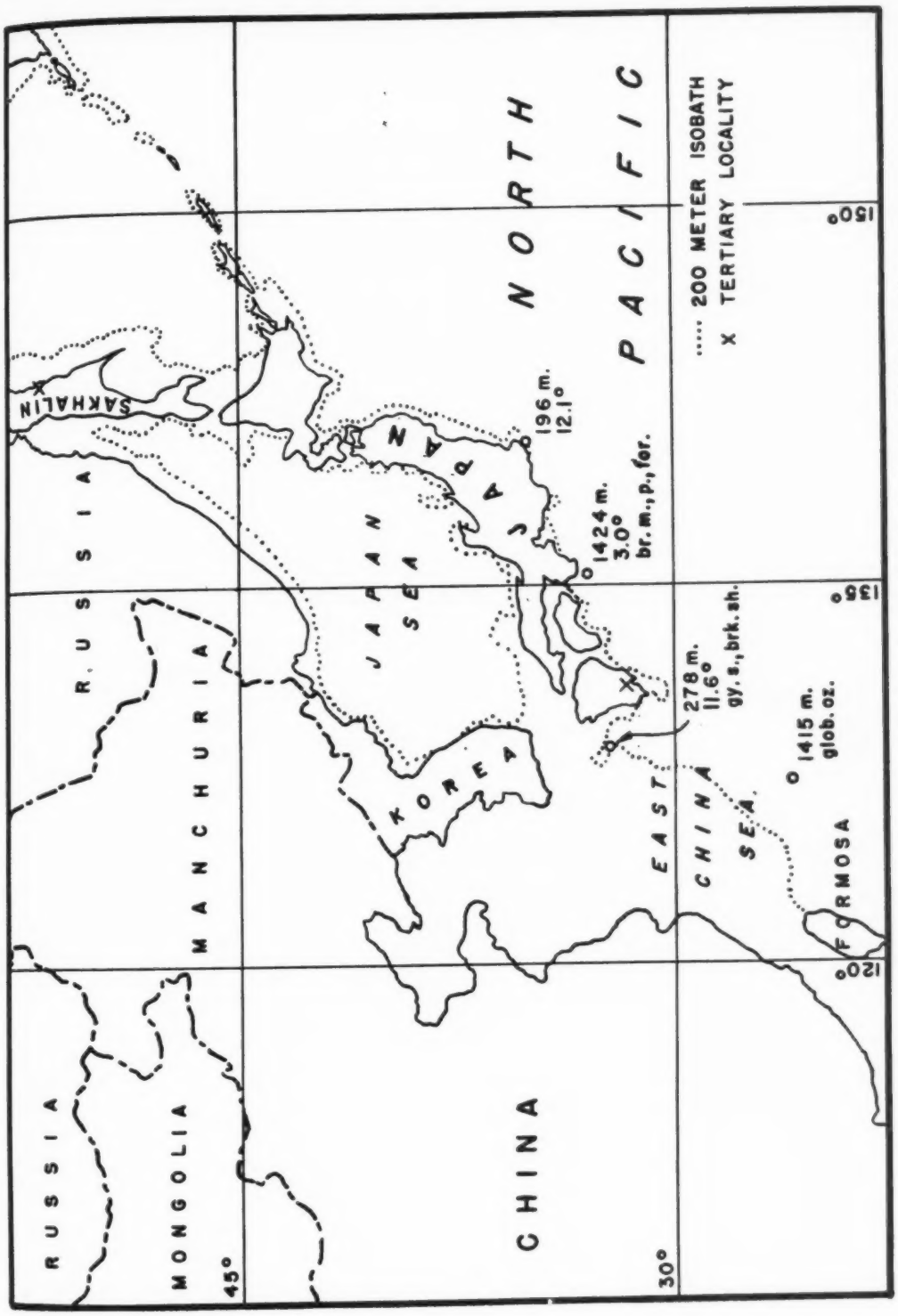

FIG. 3—Distribution of Recent and Tertiary *C. cancellata* in the Japanese-Sakhalin region.

grab samples, and corings, so that it appears that related conclusions may be reached for most of these as regards water depth, temperature, character of bottom, and probably other environmental factors. Species which have been found in association with *C. cancellata* at ten or more stations are listed as follows:

	Number of Stations
Ammodiscus incertus (d'Orbigny)	17
Ammolagena clavata (Brady)	14
Clavulina communis (d'Orbigny)	13
Dentalina communis (d'Orbigny)	10
D. soluta Reuss	10
Gyroidina soldanii (d'Orbigny)	14
Höglundina elegans (d'Orbigny)	15
Laticarinina pauperata (Parker and Jones)	14
Lenticulina rotulata (Lamarck)	14
Nonion pompilioides (Fichtel and Moll)	14
"*Nonionina*" *latidorsatum* (Bornemann)	21
Pyrgo depressa (d'Orbigny)	12
P. inflata (J. Wright)	11
Quinqueloculina seminula (Linné)	10
Reophax scorpiurus (Montfort)	14
Rhabdammina abyssorum (M. Sars)	10
Saccorhiza ramoza (Brady)	10
Uvigerina peregrina (Cushman)	12

Examination of the literature further reveals that *C. cancellata* has been found in association with the following species at seven to nine (inclusive) stations:

Ammodiscus gordialis (Jones and Parker)
Bulimina aculeata (d'Orbigny)
B. pyrula (d'Orbigny)
Cassidulina subglobosa (Brady)
Cibicides ungerianus (d'Orbigny)
Haplophragmoides scitulus (Brady)
Hyperammina elongata (Brady)
Nodosaria scalaris (d'Orbigny)
Planispirina celata (Costa)
Pullenia quinqueloba (Reuss)
"*Pulvinulina*" *micheliniana* (d'Orbigny)
Reophax nodulosus (Brady)
Robulus cultratus (Montfort)
Spiroloculina limbata (d'Orbigny)
Textularia agglutinans (d'Orbigny)
Trochammina globigeriniformis (Parker and Jones)
"*Truncatulina*" *lobatula* (Walker and Jacob)
Uvigerina asperula (Chapman)

Bottom character.—Thorough analyses of lithologies are not available for most of

TABLE 3.—*C. cancellata* STATIONS IN THE GULF OF MEXICO

Station No. (of Authors)	Latitude	Longitude	Depth (M.)	Temp. (C.)	Character of Bottom	Reference
		GULF OF MEXICO				
D2385	28 51 00 N.	88 18 00 W.	1460	4.50	Gy. M.	Cushman, 1920
D2392	28 47 30 N.	87 27 00 W.	1448	4.83	Br. Gy. M.	Cushman, 1920
D2394	28 38 30 N.	87 02 00 W.	840	5.44	Gn. M.	Cushman, 1920
D2395	28 36 15 N.	86 50 00 W.	694	6.72	Gy. M.	Cushman, 1920
34	27 45 00 N.	93 56.7 00 W.	404	—	—	Phleger, 1951
36	27 38 00 N.	93 53 00 W.	731	1.9	—	Phleger, 1951
38	27 28 00 N.	93 53 00 W.	914	—	—	Phleger, 1951
57	27 33 00 N.	94 33 00 W.	731	—	—	Phleger, 1951
66	27 41.5 00 N.	94 44 00 W.	398	—	—	Phleger, 1951
167	27 12 00 N.	95 28 00 W.	1005	—	—	Phleger, 1951
168	27 22 00 N.	95 33 00 W.	859	1.9	—	Phleger, 1951
169	27 32.5 00 N.	95 41.5 00 W.	639	—		Phleger, 1951
170	27 34 00 N.	95 43 00 W.	567	—	—	Phleger, 1951
266	27 05.5 00 N.	96 16 00 W.	430	—	—	Phleger, 1951
267	26 04.5 00 N.	96 14.5 00 W.	485	—	—	Phleger, 1951
270	26 58.5 00 N.	96 03 00 W.	759	—	—	Phleger, 1951
271	26 56 00 N.	95 58 00 W.	823	—	—	Phleger, 1951
330	25 26 00 N.	95 42.5 00 W.	1116	—	—	Phleger, 1951
472	27 34 00 N.	93 14.5 00 W.	366	—	—	Phleger, 1951
2352	22 35 00 N.	84 23 00 W.	926	—	Co.	Goës, 1896
3377	29 00 00 N.	88 00 00 W.	420	—	Gy. M.	Goës, 1896
2381	28 00 00 N.	87 56 00 W.	2660	—	Lt. Br. Glob. M.	Goës, 1896
2383	28 32 00 N.	88 00 00 W.	2362	—	Br. Gn. M.	Goës, 1896
2397–2398	28 43 00 N.	86 30 00 W.	454–560	—	Gy. Glob. M.	Goës, 1896
2400	28 04 00 N.	86 00 00 W.	392–338	—	Gy. Glob. M.	Goës, 1896

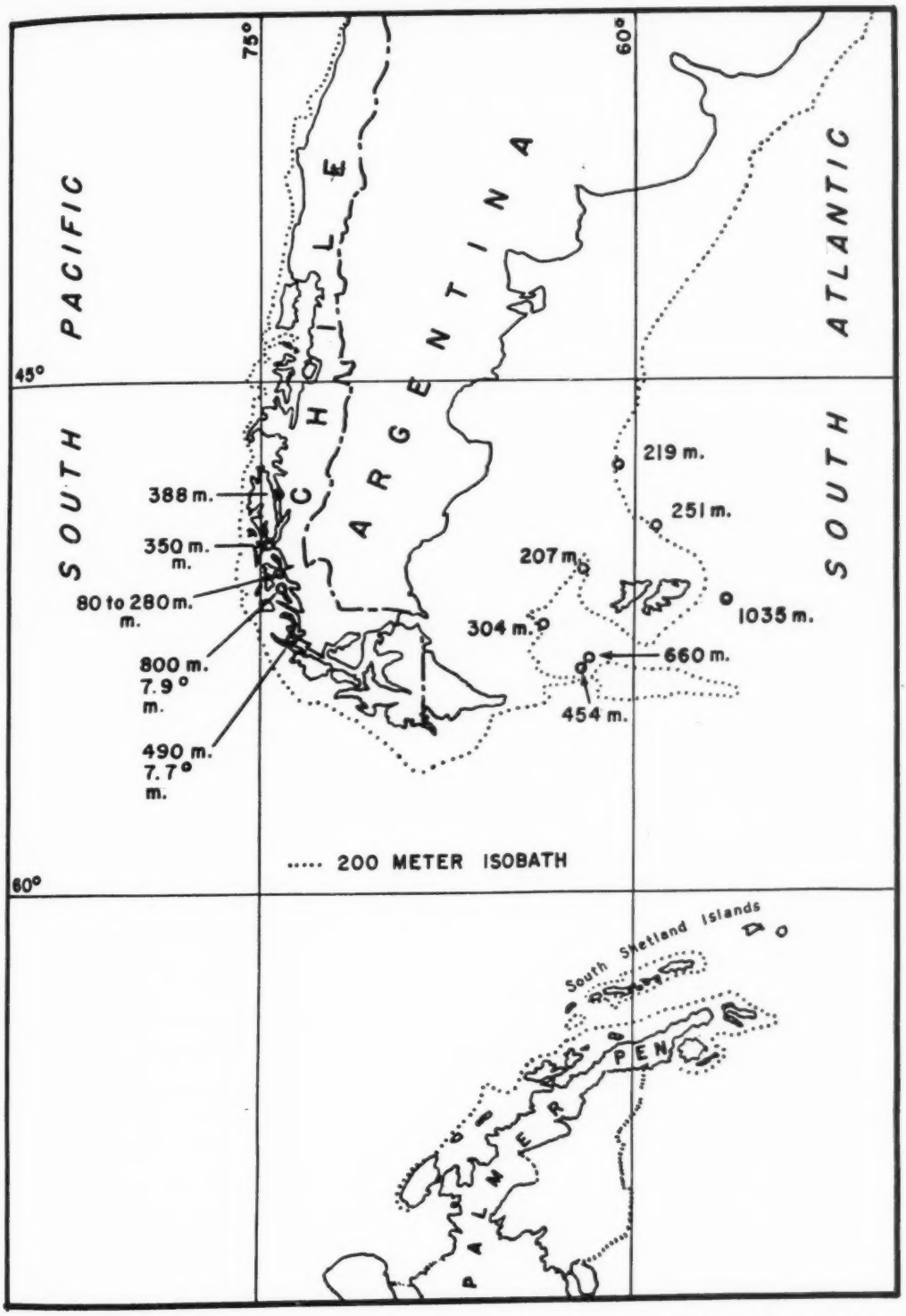

FIG. 4—Distribution of Recent *C. cancellata* in the Straits of Magellan and Falkland Island region.

the Recent localities, although they are usually described in general terms. Some aspects of this terminology are inadequate, such as the use of the word, "mud" and "sand." In the absence of more precise descriptions, repetition here of terminology previously employed in the literature is unavoidable.

The word "mud" was found to be the lithologic term most frequently employed in the *C. cancellata* literature. It is listed as the major constituent of bottom sediments at well over half of the stations which have yielded the species. These "muds" range in color from red to green with the greens being reported most often. Grays have been observed almost as often as the greens. Thus far the occurrence of the species with red "mud" has been found to be rare.

C. cancellata has been found associated with various "oozes" at numerous stations. These are frequently described as *Globigerina* and pteropod oozes. With the "muds," the "oozes" constitute the surface of the sea floor at more than 75% of the localities where *C. cancellata* has been collected. Although the species has been frequently reported in "sands" its occurrence in the coarser textured sediments, such as pebbles and gravel, is rare.

THE TERTIARY SPECIES

Venezuela.—The range of *C. cancellata* is generally accepted as Oligocene to Recent, although Nuttall (1935) mentions specimens from the upper part of the Pauji shale of Venezuela which he concedes to be of late Eocene age. According to him, "this species is somewhat variable, but no differences of specific value have been observed in the specimens examined."

C. cancellata is widespread in Tertiary sediments of tropical America. Renz (1948) notes its occurrence in the "*Uvigerinella*" *sparsicostata*, *Robulus wallacei*, *Siphogenerina transversa*, *Globorotalia fohsi*, *Valvulineria herricki*, *Marginulinopsis basispinosus*, and the *Robulus senni* zones of the Agua Salada group of eastern Falcón. It occurs in the three zones of Carapita shale in northeastern Venezuela (Hedberg, 1937, and Franklin, 1944).

TABLE 4.—*C. cancellata* STATIONS IN THE NORTH ATLANTIC OCEAN

Station No. (of Authors)	Latitude	Longitude	Depth (M.)	Temp. (C.)	Character of Bottom	Reference
NORTH ATLANTIC OCEAN						
D2150	13 34 45 N.	81 21 10 W.	764	7.64	Wh. Crs. S.	Cushman, 1920
D2202	39 38 00 N.	71 39 45 W.	1030	3.99	Gn. M.	Cushman, 1920
D2203	39 34 15 N.	71 45 15 W.	1410	3.83	Gn. M., S.	Cushman, 1920
D2204	39 30 30 N.	71 44 30 W.	1456	3.99	Br. M.	Cushman, 1920
D2212	39 59 30 N.	70 30 45 W.	856	4.44	Gn. M.	Cushman, 1920
D2213	39 58 30 N.	70 30 00 W.	768	4.16	Gn. M.	Cushman, 1920
D2234	39 09 00 N.	72 03 15 W.	1620	3.66	Gn. M.	Cushman, 1920
D2237	39 12 17 N.	72 09 30 W.	1040	4.16	Gn. M.	Cushman, 1920
D2314	32 43 00 N.	77 51 00 W.	318	8.55	Crs. S., Brk. Sh.	Cushman, 1920
D2504	44 23 00 N.	61 22 45 W.	164	4.77	Bk. M. G.	Cushman, 1920
D2677	32 39 00 N.	76 50 30 W.	956	4.05	Gn. M.	Cushman, 1920
D2678	32 40 00 N.	76 40 30 W.	1462	3.72	Lt. Gy. Oz.	Cushman, 1920
D2679	32 40 00 N.	76 40 30 W.	1564	3.66	Lt. Gy. Oz.	Cushman, 1920
D2680	39 50 00 N.	70 26 00 W.	1110	—	—	Cushman, 1920
D2689	39 42 00 N.	71 15 30 W.	1050	—	Gn. M.	Cushman, 1920
D2729	36 36 00 N.	74 32 00 W.	1358	—	Dk. Gn. M.	Cushman, 1920
D2731	36 45 00 N.	74 28 00 W.	1562	—	Gy. Oz.	Cushman, 1920
D2739	37 34 30 N.	73 58 00 W.	1622	3.44	Gy. M.	Cushman, 1920
2584	39 05 00 N.	72 23 00 W.	1082	—	—	Flint, 1897
13	8 Mi. E. of Andros Is.		1650	4.00	—	Norton, 1930
L3	51 02 00 N.	11 27 00 W.	690	—	Fne. S.	Wright, 1891
24	Off Culebra Is., West Indies, N. of St. Thomas's		780	—	M., Ptr. Oz.	Brady, 1884
85	28 42 00 N.	18 06 00 W.	2250	—	Vol. S.	Brady, 1884
5	66 59 00 N.	55 27 00 W.	114	—	S., Sh., R.	Norman, 1876
13	56 1 00 N.	34 42 00 W.	1380	3.44	Glob. Oz.	Norman, 1876

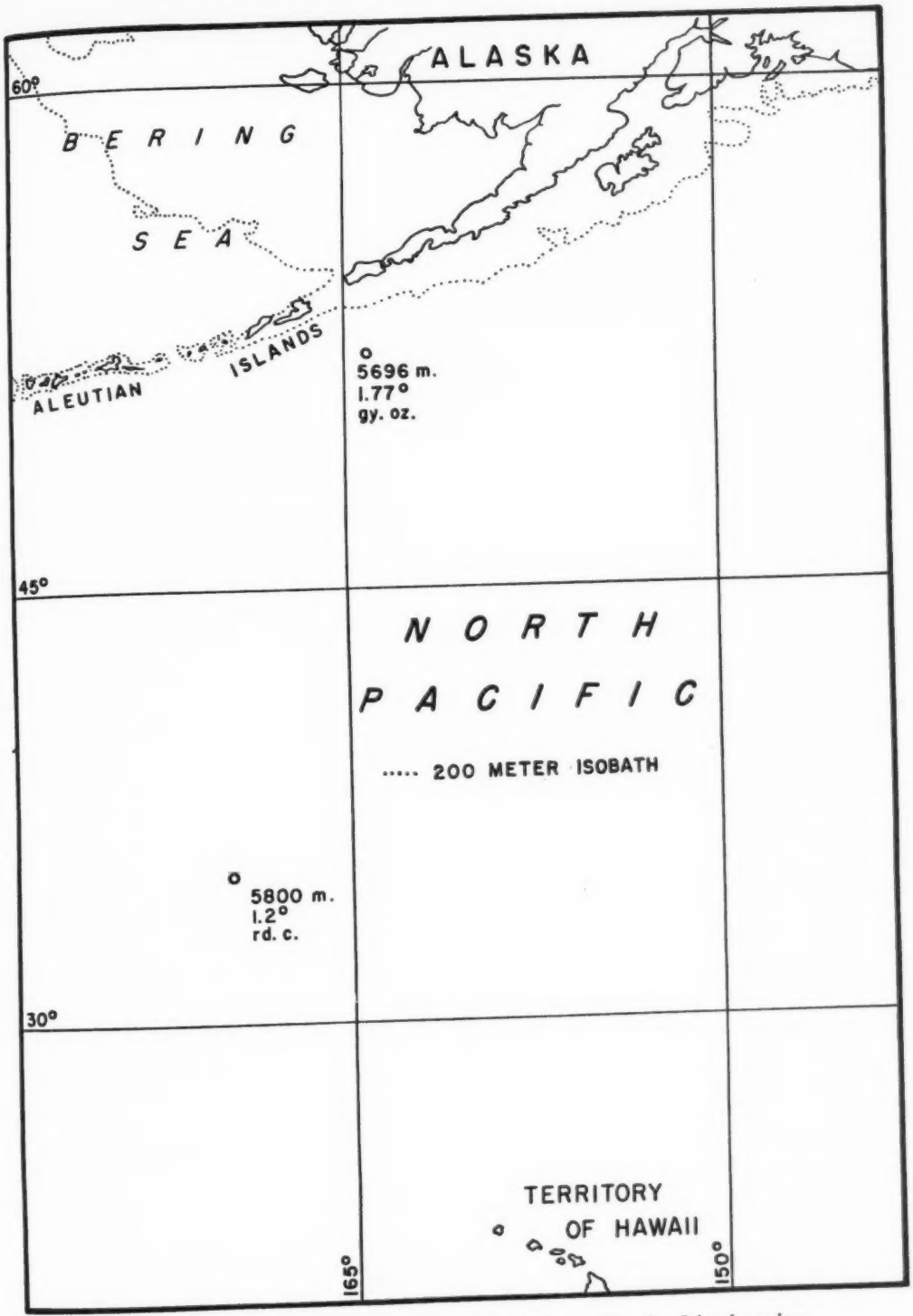

FIG. 5—*C. cancellata* stations in the Hawaiian Islands-Aleutian Islands region.

Trinidad.—In Trinidad, the species is recorded from the Ste. Croix and Brasso formations (Cushman and Renz, 1947, and Renz, 1948), the Cipero marl formation (Cushman and Stainforth, 1945, and Stainforth, 1948), and the Cruse and Forest formations (Bronnimann, 1951).

Caribbean region.—*C. cancellata* has been identified in the Finca Adelina marl of Cuba (Palmer and Bermudez, 1936) and in the Mao and Gurabo formations of the Dominican Republic (Bermudez, 1949).

America.—The earliest record of the Tertiary occurrence of *C. cancellata* in America is probably that of Bagg (1908) who reported the species from the Miocene of New Jersey. In Humboldt County, California, beds tentatively identified as Pliocene in age have yielded the species (Cushman, Stewart, and Stewart, 1930). Cushman and Laiming (1931) described a new variety of the species, *C. cancellata* var. *obesa*, from the Miocene beds at Los Saucés Creek, Ventura County, California. The authors also identified *Cyclammina incisa* (Stache) at this locality. *C. cancellata* is well represented in Miocene deposits of the Louisiana Gulf Coast. It is present in the *Uvigerina lirettensis* zone (Ellisor, 1940) and is particularly abundant in the *Planulina harangensis* zone (Ellisor, 1940, and Pope and Smith, 1948). The writer has found it in many samples from wells throughout the Louisiana Miocene trend. It often occurs in marine Miocene shale zones which also yield abundant tests of planktonic Foraminifera as well as numerous tests of other benthonics. Frequently it will be found to be extremely abundant in certain zones almost to the exclusion of other Foraminifera. This occurrence offers an interesting analogy with Recent one-genus assemblages of *Cyclammina* spp., which have been dredged from the seas surrounding the Japanese islands (Asano, personal communication, and Stainforth, 1952).

TABLE 5.—*C. cancellata* STATIONS IN THE NORTH PACIFIC OCEAN

Station No. (of Authors)	Latitude	Longitude	Depth (M.)	Temp. (C.)	Character of Bottom	Reference
		NORTH PACIFIC OCEAN				
—	35 15 10 N.	140 46 00 E.	196	12.1	—	Asano, Pers. Comm.
2860	51 23 00 N.	130 34 00 W.	1752	—	—	Flint, 1897
113	San Pedro Cnannel, Calif.		384	7	—	Natland, 1933
114	San Pedro Channel, Calif.		283	8.5	—	Natland, 1933
95	San Pedro Channel, Calif.		350	8	—	Natland, 1933
1119	25 48.3 00 N.	127 18.2 00 E.	1415	—	Glob. Oz.	Yabe & Hanzawa, 1925
244	35 22 00 N.	169 53 00 W.	5800	1.2	Rd. C.	Brady, 1884
3418	16 33 00 N.	99 52 00 W.	1320	—	Br. S.	Goës, 1896
3431	23 59 00 N.	108 40 00 W.	1990	—	Lt. Br. Glob. M.	Goës, 1896
D5236	8 50 45 N.	126 26 52 E.	988	5.1	Fne. Gy. S.	Cushman, 1921
D5301	20 37 00 N.	115 53 00 E.	416	10.2	Gy. M., S.	Cushman, 1921
D5423	9 38 30 N.	121 11 00 E.	1016	9.9	Gy. M., Co. S.	Cushman, 1921
D5424	9 37 05 N.	121 12 37 E.	680	10.2	Co. S.	Cushman, 1921
D5425	9 37 45 N.	121 11 00 E.	990	9.6	Gy. M., Co. S.	Cushman, 1921
D5439	15 58 15 N.	119 40 20 E.	1880	2.6	Gn.M	Cushman, 1921
D5460	13 32 30 N.	123 58 06 E.	1130	—	Gn. M.	Cushman, 1921
D5468	13 35 39 N.	123 40 28 E.	1018	—	Gn. M.	Cushman, 1921
D5469	13 36 48 N.	123 38 24 E.	1000	—	Gn. M.	Cushman, 1921
D5470	13 37 30 N.	123 41 09 E.	1120	—	M.	Cushman, 1921
D5619	0 35 00 N.	127 14 40 E.	870	—	Fne. Gy. S., M.	Cushman, 1921
D5529	9 23 45 N.	123 39 30 E.	882	11.6	Gy. M. Glob.	Cushman, 1921
D3346	45 30 00 N.	124 52 00 W.	1572	2.9	Gn. M.	Cushman, 1910
D4900	32 28 50 N.	128 34 40 E.	278	11.6	Gy S., Brk. Sh.	Cushman, 1910
D4975	33 21 30 N.	135 38 50 E.	1424	3.0	Br. M., P., For.	Cushman, 1910
H1135	52 18 00 N.	163 54 00 W.	5696	1.77	Gy. Oz.	Cushman, 1910
D4174	"Near the Hawaiian Islands"		1470–1730	3.33	Glob. Oz.	Bagg, 1908
H4508	"Near the Hawaiian Islands"		990	—	—	Bagg, 1908

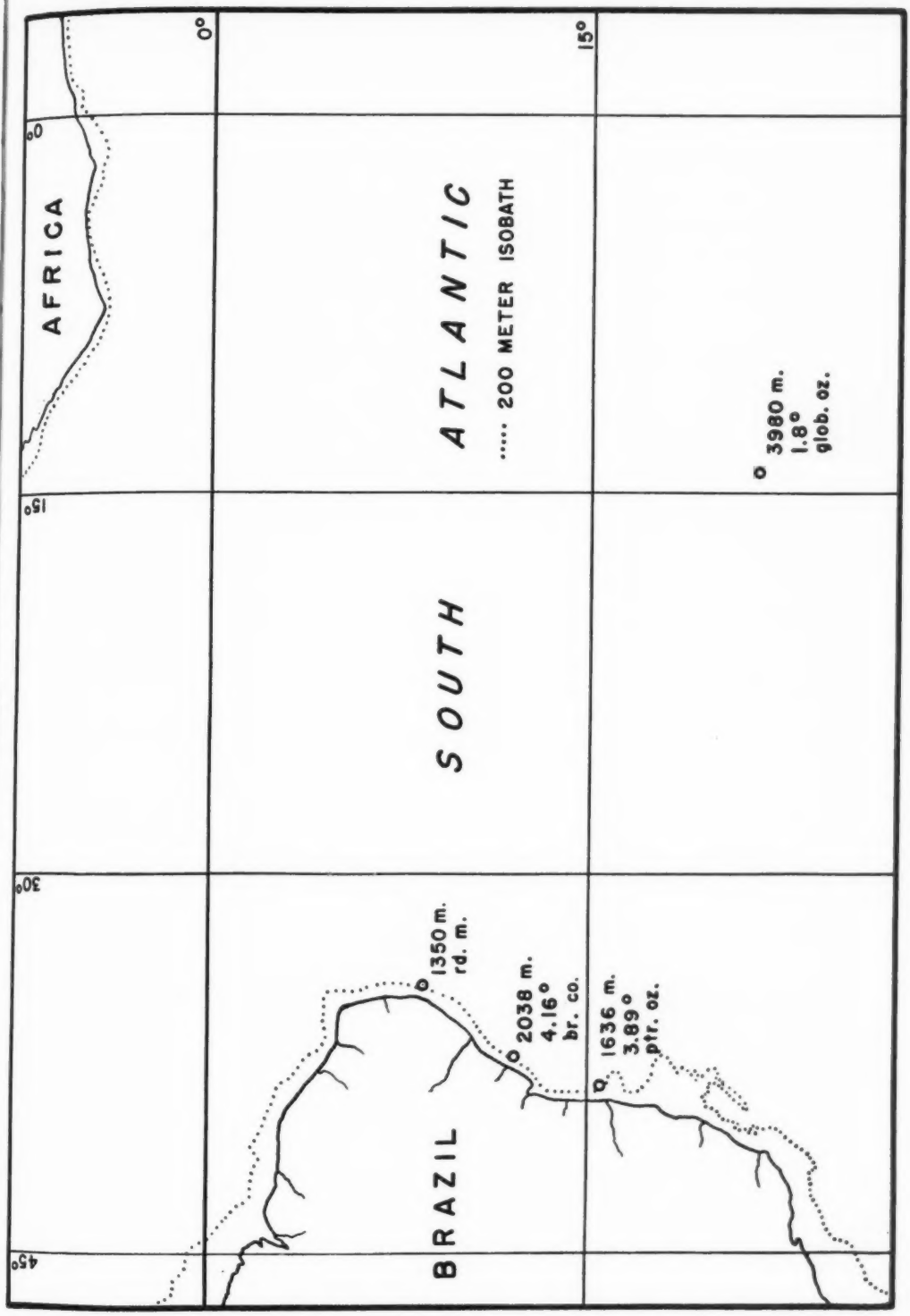

FIG. 6—Distribution of Recent *C. cancellata* in the South Atlantic.

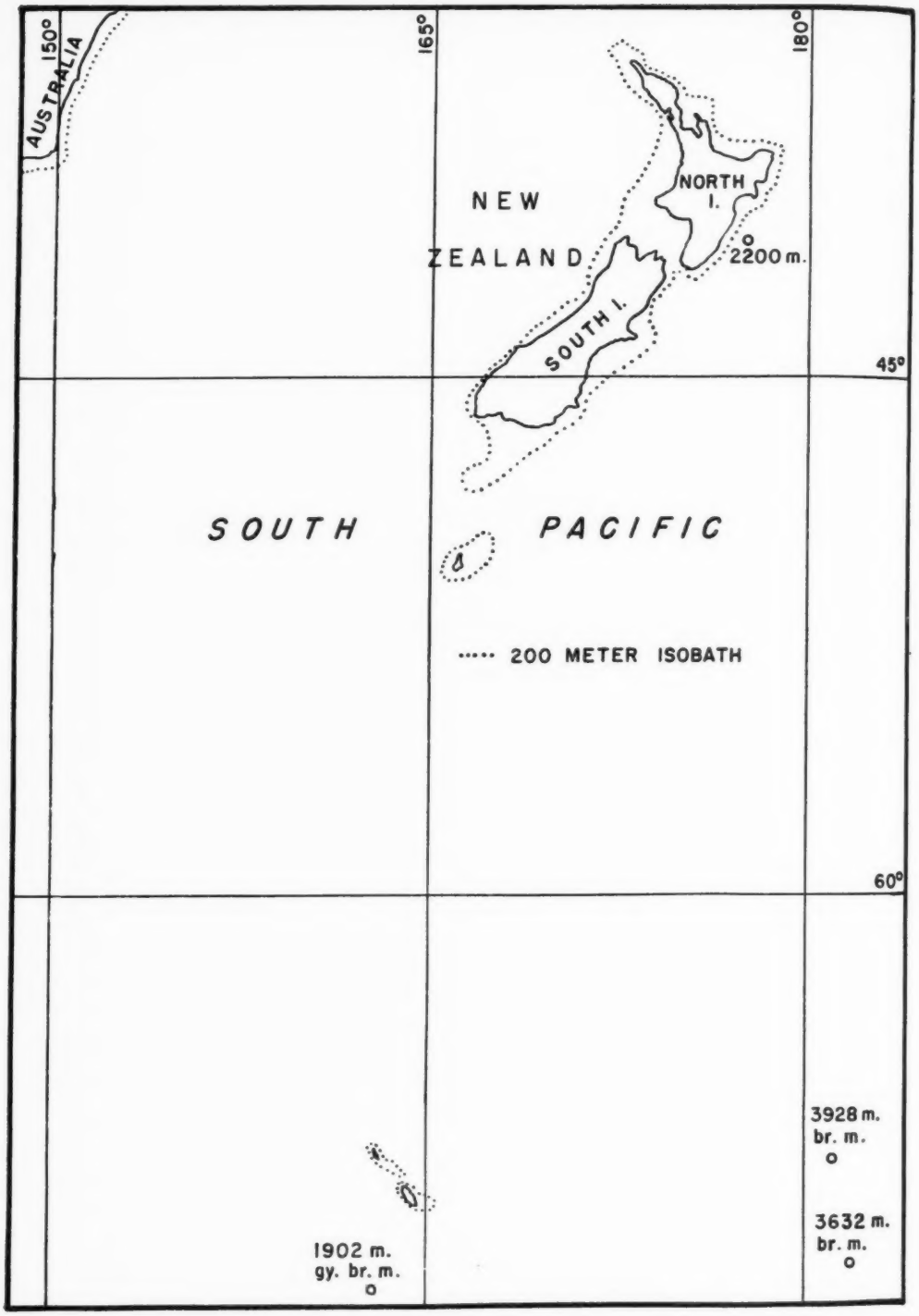

FIG. 7—*C. cancellata* stations in the New Zealand-Antarctica region.

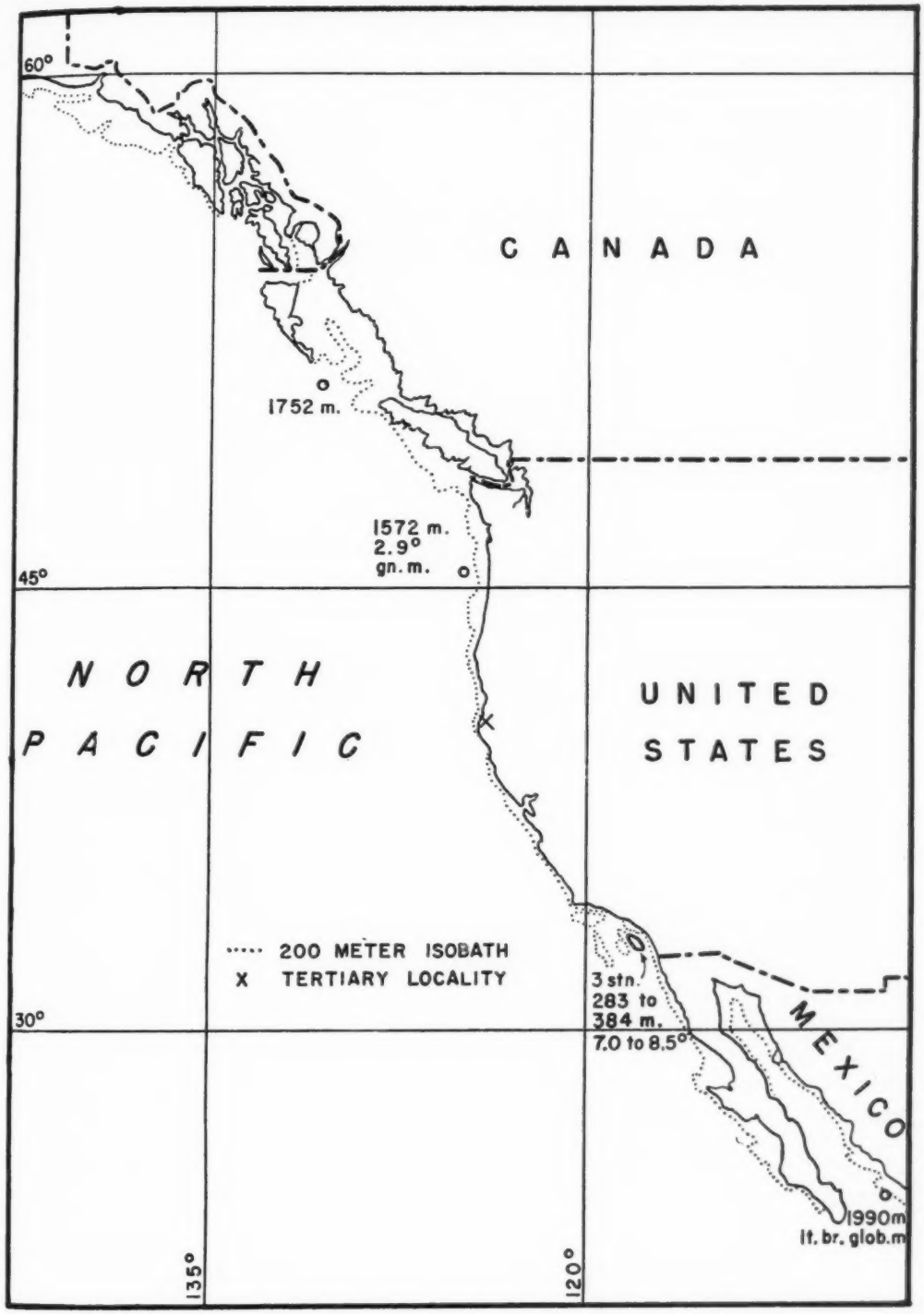

FIG. 8—Distribution of Recent and Tertiary *C. cancellata* along the Pacific Coast of North America.

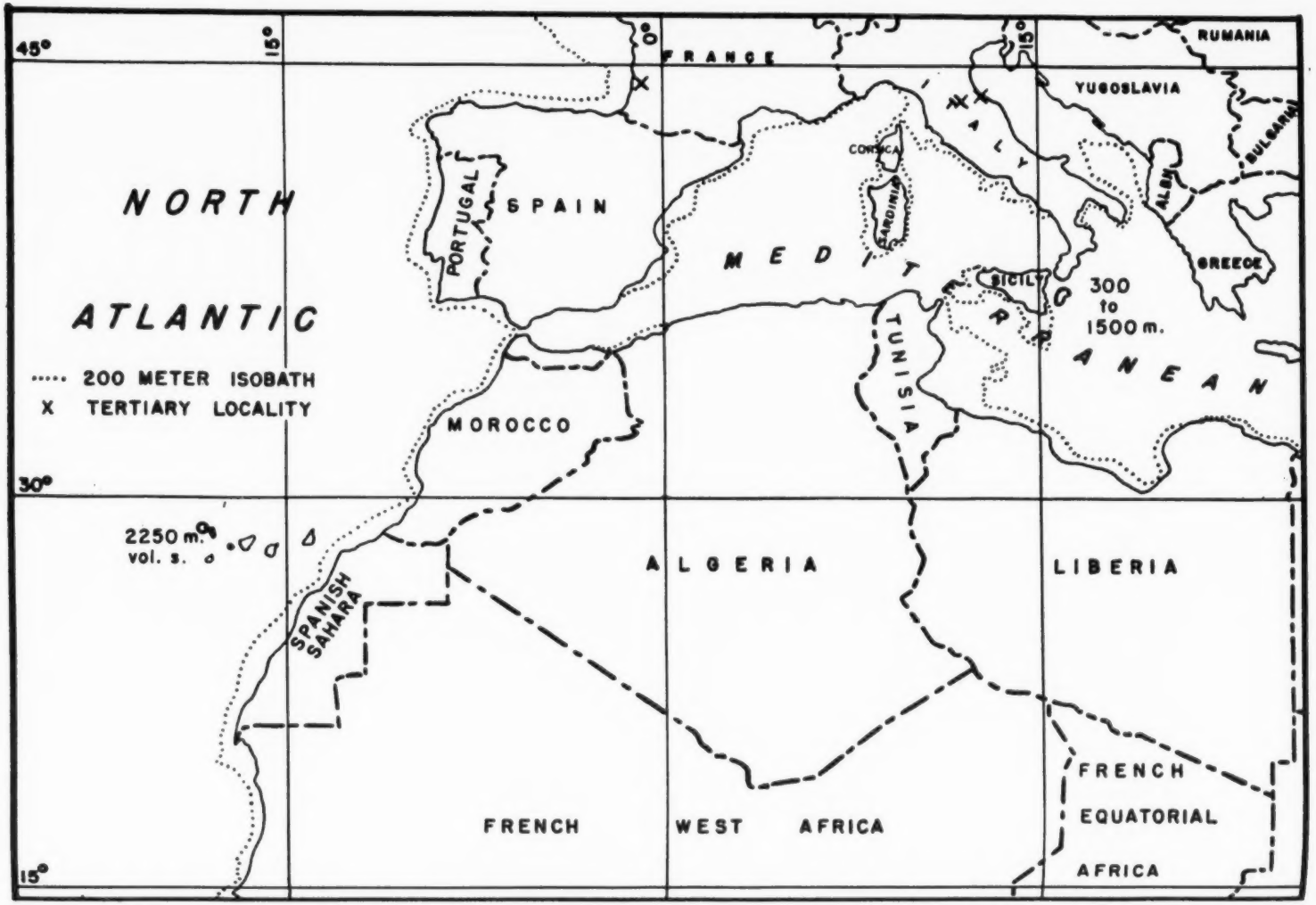

FIG. 9—Recent and Tertiary distribution of *C. cancellata* in the South European-North African region.

FIG. 9—Recent and Tertiary distribution of *C. cancellata* in the South European-North African region.

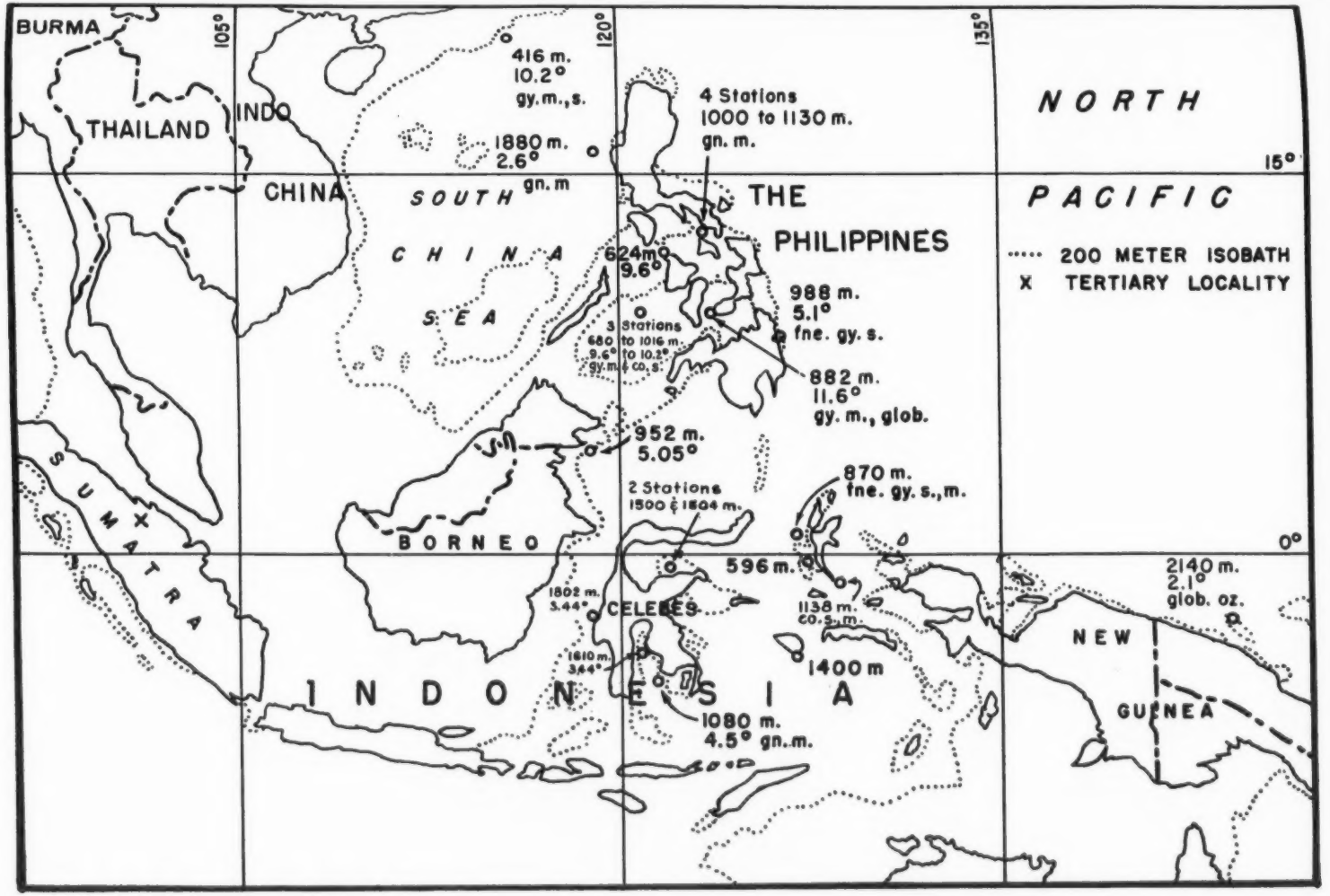

FIG. *10*—Recent and Tertiary distribution of *C. cancellata* in the Indonesian-Philippine region.

A shale core (−10,132 to −10,142 feet) from the *Globorotalia fohsi* zone of a Lirette Field well (Humble Ellender #1, Sec. 23, Township 19 South, Range 19 East, Terrebonne Parish, Louisiana) was found to have a foraminiferal number (number of Foraminifera in one gram of sample) of 417. The planktonic foraminiferal component of this number was 340; the calcareous benthonic component, 71; and the arenaceous benthonic, 6. Representatives of the two genera, *Bolivina* and *Uvigerina*, constituted 60 percent of the benthonics, while *C. cancellata* was relatively rare, only three specimens being yielded by 7 grams of unreduced sample from this zone. This foraminiferal shale was dark gray to brown in color, rather massively bedded, and contained very few quartz sand grains. The core was taken from a shale bed whose thickness, as measured on the electrical log, is 270 feet. Other distinctive benthonic Foraminifera from cores within this interval include *Gyroidina scalata* Garrett, *Cibicides carstensi* Cushman and Ellisor, *Eggerella scabra* (Williamson), *Uvigerina lirettensis* Cushman and Ellisor, *Siphogenerina lamellata* Cushman, *Textularia tatumi* Cushman and Ellisor, and *Globobulimina pupoides* (d'Orbigny).

Europe.—The European Tertiary occurrence of *C. cancellata* was first discussed in detail by Silvestri (1895 and 1896), who described specimens from several Pliocene localities near Siena, Italy, and compared them with Brady's Recent types. Recently, Ruggieri (personal communication) has identified middle Pliocene forms of the species from a blue marly clay at Castellarquato, near Piacenza, Italy. A few specimens have been found in the middle Miocene beds of a well at Saubrigues, France (Cuvillier and Szakall, 1949), which closely resemble those from Castellarquato, the Italian forms being somewhat larger, however. Sacal (personal communication) has compared the specimens from Saubrigues with those from the Tortonian of Morocco, which are also said to be larger than those from Saubrigues.

Asia.—Voloshinova (1935) has compared Miocene and lower Pliocene specimens of *C. cancellata* from wells in the Okhi area of Sakhalin Island with those described by Cushman, Stewart, and Stewart (1930) from Humboldt County, California. In both cases, the tests are white in color. The Okhi area is further interesting because of a zone containing abundant arenaceous Foraminifera of the family Lituolidae almost to the exclusion of all other types.

The genus *Cyclammina* has been termed "the characteristic genus of the Japanese Miocene," although representatives are also known from marine facies of the Eocene and Oligocene of Japan (Murato, 1951). *Cyclammina* cf. *C. cancellata* and *C. incisa* were identified from several sections in the Miyazaki group (upper Miocene) of the Hyúga Plain. Unfortunately, paleoecologic data are unavailable from this area.

C. cancellata has been noted in appreciable numbers from the lower Palembang (Miocene) of central Sumatra (LeRoy, 1944). This formation consists of a series of dark-green foraminiferal shales containing thin layers of silt and glauconite. Although lower Palembang foraminiferal assemblages are quite varied both in species and genera, globigerine forms predominate in all assemblages, according to LeRoy.

CONCLUSIONS

The early summation of Brady (1884) is still generally applicable. He concluded from his studies of the *Challenger* dredgings that "the geographical distribution of *Cyclammina cancellata* embraces a very wide area, and its bathymetrical range extends from 75 fathoms to 2900 fathoms, though it cannot be said to flourish at depths of less than 250 or more than 1000 fathoms." To this may be added the observation that temperature appears to be one of the most influential of all the factors involved in the ecology of this species. That temperature plays a major role is indicated by the relatively low readings at those *C. cancellata* stations where the water depth is shallowest. The apparent confinement of the species to water depths greater than those on the continental shelf may be due to an intolerance for seasonal effects, which extend only to 100 m.–200 m. It has been shown that temperatures below that depth show little or no variation throughout the year (Phleger, 1951).

Although the finer sediments, "muds" and oozes, are reported from the majority of the *C. cancellata* stations, it is still problematic as to whether the species actually prefers this type of bottom to the coarser sediments. The bottom sediments may determine the texture of the test, at least to some extent, since specimens from some localities consistently employ larger grains than do others. A tendency to utilize what happens to be at hand has been observed in other members of the Lituolidae, which have been maintained in aquaria in The California Company Paleontological Laboratory. These have been seen to use various amounts of carborundum in their tests, depending upon the supply.

The density of *C. cancellata* stations off the continental shelves of landmasses whose Tertiary rocks have yielded this species (figs. 1 to 10) suggests that its marine environment has merely regressed and that now it must be living under conditions very similar to those which composed its Tertiary milieu.

Most of the zones of the Venezuelan Agua Salada group in which *C. cancellata* occurs are considered to have been laid down under typical open-sea marine conditions at medium depths along the slope of the continental shelf not far from a landmass. Renz (1948) believes that these sediments were deposited in Phleger's Slope Zone 1 (1939–1942), 200 to 600 meters deep, at temperatures between 4.8°C. and 13°C. This interpretation is in accord with the data afforded by *C. cancellata* alone, although Renz analyzed considerably more ecologic information to arrive at his determinations.

The Cipero marl of Trinidad is thought to be a "fossil *Globigerina* ooze deposited in the open sea at depths of 400–500 meters" (Stainforth, 1948). Rocks composed mainly of foraminiferal pelagics and containing *C. cancellata* certainly would seem indicative of deposition at considerable depth in marine water undiluted by streams.

In the Louisiana subsurface, Harang faunas, in which *C. cancellata* is particularly abundant, are considered on the basis of their gross aspects to have been deposited at depths between 200 and 1000 meters with temperatures between 3.3°C. and 6.1°C. (Pope and Smith, 1948). Alternations of these and other *Cyclammina* beds of the Louisiana Miocene with *Rotalia-Elphidium* clays and sands would seem to point, then, to cyclic deposition under bathyal to restricted marine conditions (see Israelsky, 1949).

Those marine arenaceous assemblages which include few or no calcareous tests may have been affected chemically, so that the calcium carbonate was removed. The environment of such arenaceous associations and that of the shallow, brackish water arenaceous assemblages may be similar in a deficiency of oxygen, but it is difficult to understand the lack of pelagic tests in some of the marine samples in which *C. cancellata* and other siliceously agglutinated types are abundant. An adequate explanation for this phenomenon will have to wait for further observations, although Stainforth (1952) may be close to the answer in his suggestion of turbidity as the controlling ecologic factor.

Although the present paper is concerned with a single species, it was discovered in this case that what is true of the species is also true of the genus. In contrast with some other genera of the Lituolidae, particularly *Haplophragmoides* and *Ammobaculites*, in which some species are strictly marine, while others are confined to shallow brackish water environments, all known species of *Cyclammina* are marine and most abundant throughout the world below continental shelf depths. Lowman (1949), for example, has plotted the occurrence of members of this genus off Louisiana below 300 meters. Other species of *Cyclammina* have been collected with *C. cancellata* at many oceanographic stations, and these are often present under conditions which are apparently favorable also for the subject species, although it may be absent. In a similar manner other species of the genus are often found associated with *C. cancellata* in Tertiary sediments.

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JURASSIC OSTRACODA FROM THE "LOWER SUNDANCE" AND RIERDON FORMATIONS, WESTERN INTERIOR UNITED STATES[1]

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ABSTRACT—Twenty-two species of Upper Jurassic (Callovian) Ostracoda are described from the "lower Sundance" formation of Wyoming and South Dakota and the Rierdon formation of Montana. The assemblage includes two genera of the family Cytherellidae, one genus of the Bairdiidae, one genus of the Cypridae, and 10 genera of the Cytheridae. Some general comments are made concerning the stratigraphic and geographic distribution of the ostracodes.

INTRODUCTION

NINE species of Upper Jurassic marine Ostracoda from the type locality of the Redwater shale member of the upper part of the Sundance formation in the Black Hills have been described (Swain and Peterson, 1951). Seven additional species from equivalent beds at other localities in the Black Hills, eastern Wyoming, and southern Montana, are described in a subsequent paper (Swain and Peterson, 1952). All of these species are listed in table 2. The present paper describes ostracodes from the "lower Sundance" and Rierdon formations and in addition summarizes the recorded occurrences of ostracodes in the Swift formation of Montana, the "upper Sundance" formation of Wyoming, and the Redwater shale member of the Sundance formation of the Black Hills.

The marine Upper Jurassic rocks of Wyoming and Montana and the adjacent area to the east consist of the Sundance formation in Wyoming and the Black Hills and the Swift and Rierdon formations of the Ellis group in Montana. Studies of the mollusks by Imlay (1947, 1948, 1953) have shown that the "upper" and "lower Sundance," respectively, of Wyoming are faunally equivalent to the Swift formation and the underlying Rierdon formation of Montana and to the Redwater and the pre-Redwater members of the Sundance formation of the Black Hills. In south-central and eastern Wyoming, the "lower Sundance" formation consists of an alternating sequence of gray to buff sandstones and green shales overlain by a persistent red bed unit known as the "Sundance red." These beds are lithologically similar to the pre-Redwater members of the Sundance formation in the Black Hills, but in north-central Wyoming and southern Montana they grade into the limy shales, oolitic limestones, and infrequent sandstones of the Rierdon formation. The "lower Sundance," Rierdon, and pre-Redwater beds are overlain by the gray to greenish-gray shales and glauconitic sandstones of the "upper Sundance" formation in Wyoming, the Swift formation in Montana, and the Redwater member of the Sundance formation in the Black Hills. In south-central and southeastern Wyoming, the "lower Sundance" formation disconformably overlies rocks ranging in age from the Triassic Chugwater or Spearfish formations to the Middle Jurassic Gypsum Spring formation. A similar relationship exists in the Black Hills between the pre-Redwater beds and the underlying rocks. In Montana, the Rierdon formation overlies the Middle Jurassic Piper or Sawtooth formation, except for a portion of central Montana (Belt Island) where it overlies Paleozoic rocks (fig. 3).

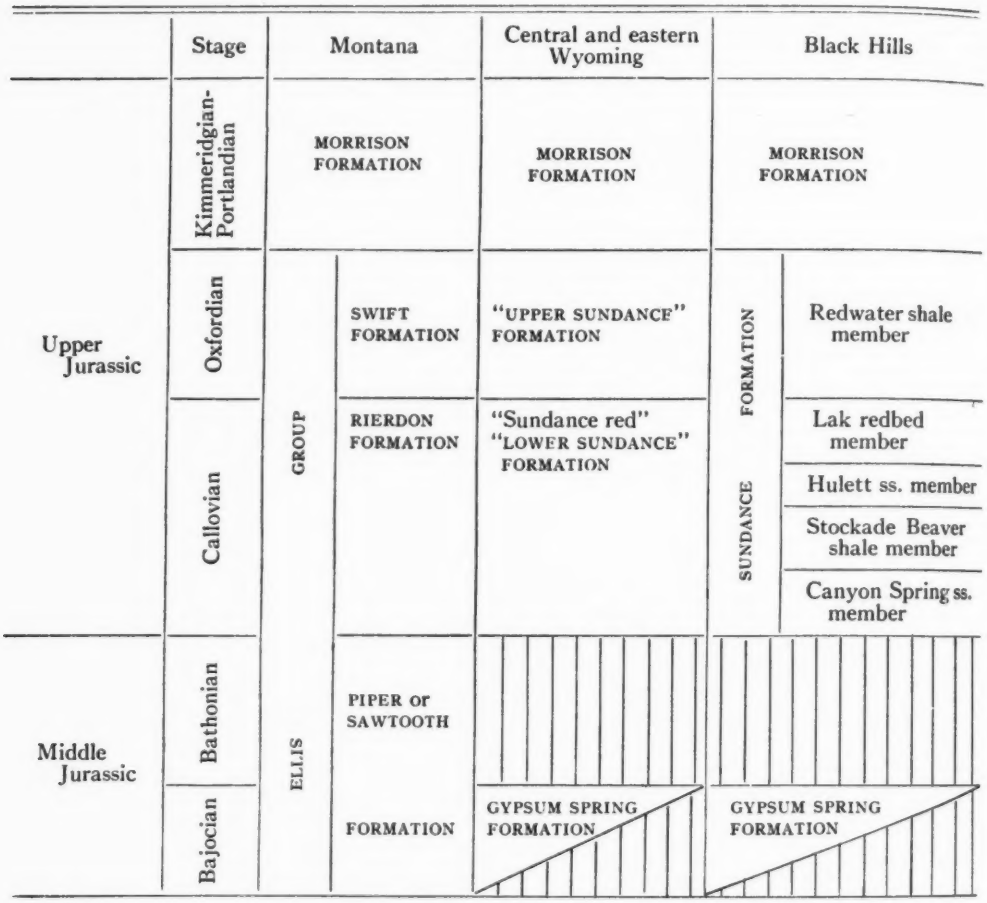
In many places, particularly in central Montana and central and southern Wyoming, stratigraphic and faunal evidence indicates the presence of a minor disconformity between the "upper" and "lower Sundance" formations, and the Swift and Rierdon formations. Throughout the area covered by the present study, the marine Upper Jurassic rocks are overlain conform-

[1] Publication authorized by the Director, U. S. Geological Survey.
[2] Now with Shell Oil Co., Salt Lake City, Utah.

ably by the non-marine Upper Jurassic Morrison formation.

An accurate determination of the stratigraphic position of each sample studied for microfossil content can be obtained from table 1 (e.g., sample Js-III d is taken from shale beds 19–25 feet above the base of the "lower Sundance" formation, etc.).

tively. These are only generalized indications of abundance because the specimens were removed from channel samples that represent variable stratigraphic intervals (see table 1). The localities are described on pages 156–158, and the stratigraphic positions of the individual samples are shown in table 1.



ADDITIONAL OSTRACODA FROM THE "UPPER SUNDANCE" FORMATION

During the course of the present work several additional occurrences of "upper Sundance" ostracodes in eastern Wyoming were noted and are listed below. Abundance of occurrence is given as follows: 1–4 (R), 5–9 (LC), 10–19 (C), 20–39 (A), 40 plus (VA), denoting rare, less common, common, abundant, and very abundant, respec-

Aparchitocythere loeblichorum (Swain and Peterson), 1951, Loc. Js-I ii, jj, (R); Js-III gg (R).

Aparchitocythere typica Swain and Peterson, 1952, Loc. Js-I jj, kk, ll, mm, nn, oo (C to A); Js-II, kk, ll, mm, nn, oo, qq, rr, ss, tt, uu (C to A); Js-III, ii, kk, ll, mm, nn, oo, pp, rr, ss (C to A); Js-VI gg (R to LC); Js-VIII nn, pp, rr, uu, vv, ww, xx, yy, zz (C to A).

Camptocythere elliptica Swain and Peterson, 1952, Loc. Js-I ii, jj, kk (R to LC); Js-II jj, kk, mm, pp (R); Js-III ll, nn (R); Js-VIII yy (R).

Cythereis zygoventralis Swain and Peterson, 1952, Loc. Js-I jj, kk, mm, nn (LC to A); Js-II

Spl. \ Loc.	Js-I	Js-II	Js-III	Js-IV	Js-VI	Js-VIII	Js-IX	Js-X	Js-XI	Js-XII	Js-XIII	Js-XIV	Js-XV	Js-XVI	Js-XVII	Js-XVIII	Js-XX
	"UPPER SUNDANCE" OR REDWATER SHALE MEMBER OF SUNDANCE FORMATION												SWIFT FORMATION				
zz		*296–311*				113–117*											
yy		*285–296*				108–111*											
xx		277–285				106–108*											
ww		269–277				104–106*											
vv		257–269				102–104*											
uu		245–257*				100–102*											
tt		241–245*	292–302*			92–95*											
ss	*237–246*	229–241*	282–292*	*161–167*		89–92*											
rr	*234–237*	223–229*	272–282*	(153–157)		84–89*											
qq	231–234	213–223*	252–270*	*150–153*		79–84*											
pp	224–231	203–213*	236–252*	142–150		74–79*							145–152*				61–63
oo	211–224*	(201–203)*	227–236*	134–142		69–74							137–145*				57–59
nn	199–211*	190–201*	215–227*	126–134		64–69*							130–137*				55–57
mm	183–199*	179–190*	211–215*	118–126		59–64							122–130*				52–54
ll	175–183*	169–179*	203–211*	109–118		54–59*				105–126			117–122*				49–51*
kk	151–175*	149–169*	193–203*	100–109		49–54				100–105			112–117*				44–46
jj	137–151*	129–149*	183–191	90–100	*117–128*	44–49				93–100			107–112*	*70–75*			36–38*
ii	120–137*	109–129	174–183*	79–90*	106–117*	39–44*				86–93*			102–107*	45–51*			32–34
hh	103–120	89–109	160–174	70–79	95–106	34–39			95–106	80–86			97–102*	40–45*			28–30*
gg	86–103	*74–89*	155–160*	56–70*	83–95*	29–34			85–95*	73–80*			92–97*	37–40*			24–26*
ff	69–86	*38–74**	111–153	*41–56*	75–83*	24–29			77–85*	66–73*			86–92*	29–33*			21–23*
ee	54–69*	*35–38*	93–111	33–41	67–75*	19–24			69–77*	59–66*	81–88*		80–86*	24–26*			18–20
dd	39–54*	28–35	78–93	25–33	44–60	14–19			59–69	51–59*	74–81*	50–57*	68–80*	20–23*			12–14*
cc	24–39	18–28	43–78	20–25	40–44	9–14		*10–15**	49–59*	40–51*	33–41	45–50	58–68*	*15–17**			8–10*
bb	11–24*	*15–18*	7–33	10–20	24–40	3–6		*5–10**	21–22	33–40*	28–33	*17–20*	48–58*	*3–7**	5–20		3–5*
aa	0–11*	0–15	0–7*	2–10	20–24	0–3*		*0–5*	1–8	23–33	7–25	*9–12*	11–21*	*0–3**	0–5*	0–5*	0–2*
	"LOWER SUNDANCE"												RIERDON FORMATION				
t				221–229													
s				213–221				*160–165*									
r				203–213				*157–160*									
q				*197–203*				144–157									
p				189–197				134–144									
o				179–189			75–83*	129–134*									
n				169–179			66–75*	124–129									
m				148–169			57–66*	114–124					68–76				
l				137–148			51–57*	104–114					60–68				
k				127–137*		207–229	*46–51**	97–104*					52–57*	140–145*			
j				117–127*		187–207	40–46	94–97*					47–52*	105–110			
i			(81–85)	107–116*		167–187	33–40	84–94					42–47	85–90*		62–65	
h			*61–81*	96–107*		147–167	26–33	74–84					37–42	60–62*		58–60	
g			*46–61*	*74–96*		117–137	19–26	64–74					32–37	45–47*		43–45	
f			*31–46*	*67–74*		101–117*	14–19	54–64					27–32	38–40*		33–36	
e	(28–30)		25–31*	*52–67*		85–101*	12–14	44–54					22–27	32–35		27–30	
d	24–28*	*35–41**	19–25*	*35–52*		69–85*	*9–12*	34–44					17–22	30–32		19–21	
c	*15–24*	*20–35*	13–19*	*21–35*		53–69*	7–9	24–34					12–17	4–5		14–16*	
b	6–15*	10–20*	7–13*	*7–21*		37–53*	*3–7*	14–24					7–12	(1–4)		8–10	(75+)
a	0–6	0–10*	1–7*	0–7		35–37*	0–3	0–14					0–7	0–1		2–6	(55+)

TABLE 1.—Chart showing stratigraphic position of rock samples studied for microfossil content. Distances above base of member or formation are given in feet. Sandy intervals are italicized and limestone intervals are enclosed in parentheses; remainder are silty or shaly intervals. Asterisk indicates sample yielded marine ostracodes. Localities Js-V, Js-VII, Js-XIX, and Js-XXI yielded no ostracodes, hence are not included in table. Description of localities is given on pp. 156 and 158.

kk, mm, nn, pp, qq, ss, tt, uu (LC to A); Js-III ll, mm, nn, oo (C to A); Js-VIII yy (R).

Cytherella paramuensteri Swain and Peterson, 1952, Loc. Js-I, aa, jj, kk, ll, mm (R to C); Js-II ff, kk, mm, nn, pp, qq, ss (C to A); Js-III aa, ii, kk, ll, mm, nn, oo (C to A); Js-VI ee, gg (R to LC); Js-VIII uu, vv, ww, xx, yy, zz (C to A).

Cytherella ventropleura Swain and Peterson, 1952, Loc. Js-I mm, (R).

Leptocythere imlayi Swain and Peterson, 1951, Loc. Js-II pp, rr (R).

Macrocypris minutus Swain and Peterson, 1952, Loc. Js-II pp (R to LC); Js-III mm (R).

Monoceratina sundancensis Swain and Peterson, 1951, Loc. Js-I jj (R); Js-II nn (R); Js-III ll, mm (R).

Progonocythere crowcreekensis Swain and Peterson, 1951, Loc. Js-II ll (R); Js-III ii, kk (R); Js-VI gg (R); Js-VIII ll (R).

Progonocythere hieroglyphica Swain and Peterson, 1951, Loc. Js-III ii (R); Js-IV gg (R); Js-VI ee, ff, gg (R to C); Js-VIII ii, xx (R to LC).

"LOWER SUNDANCE" AND RIERDON OSTRACODA

The present paper describes or records the following species of marine ostracodes from the lower part of the Sundance formation of Wyoming and South Dakota and the Rierdon formation of the Ellis group in Montana:

CYTHERELLIDAE

Cytherella paramuensteri Swain and Peterson, 1952

Cytherelloidea recurvata Peterson, n. sp.

BAIRDIIDAE

Bythocypris jurassica Peterson, n. sp.

Bythocypris ambitruncata Peterson, n. sp.

CYPRIDAE

Paracypris projecta Peterson, n. sp.

CYTHERIDAE

Orthonotacythere dorsoconvexa Peterson, n. sp.

Monoceratina incisa Peterson, n. sp.

Monoceratina pararossae Peterson, n. sp.

Monoceratina sundancensis Swain and Peterson, 1951

Progonocythere anoda Peterson, n. sp.

Protocythere pyriforma Peterson, n. sp.

Protocythere cf. *P. quadricarinata* Swain and Peterson, 1952

Aparchitocythere compressa Peterson, n. sp.

Aparchitocythere elongata Peterson, n. sp.

Eucytherura reticulata Peterson, n. sp.

Paracytheridea polyornata Peterson, n. sp.

Cytheropteron (*Eocytheropteron*)? *lanceolata* Peterson, n. sp.

Cytheropteron (*Eocytheropteron*)? *scalpella* Peterson, n. sp.

Procytheridea exampla Peterson, n. gen., n. sp.

Procytheridea crassa Peterson, n. sp.

Procytheridea minuta Peterson, n. sp.

Cythereis heteromorpha Peterson, n. sp.

LOCALITIES

For the present study, samples were collected from marine Jurassic rocks at the localities given below (see text fig. 1). General information on each locality is incorporated in table 1.

Collections from the following localities were made in September, 1948, by R. W. Imlay and A. R. Loeblich, Jr.

1. Loc. Js-XI. Sundance formation, 1 mile north-northeast of Spearfish, sec. 3, T. 6 N., R. 2 E., Lawrence County, South Dakota.
2. Loc. Js-XII. Redwater shale member of Sundance formation, half a mile north of Redwater Creek opposite the mouth of Crow Creek, about 7 miles northwest of Spearfish, S½ sec. 2, T. 7 N., R. 1 E., Butte County, South Dakota (type locality of the Redwater shale member of the Sundance formation).
3. Loc. Js-XIII. Sundance formation, west side of Stockade Beaver Creek, 5 miles northeast of Newcastle, sec. 18, T. 45 N., R. 60 W., Weston County, Wyoming (type locality of the Stockade Beaver shale and the Lak members of the Sundance formation).
4. Loc. Js-XIV. Sundance formation, about 3 miles west-northwest of Minnekahta, N½ sec. 14, T. 7 S., R. 3 E., Fall River County, South Dakota.
5. Loc. Js-XV. Rierdon and Swift formations, east side of Red Gulch about 2½ miles south of Little Horn River, sec. 22, T. 58 N., R. 89 W., Sheridan County, Wyoming.
6. Loc. Js-XVI. Rierdon and Swift formations, at southwest corner of Red Dome, east of Bridger, in Pryor Mountains, sec. 19, T. 7 S., R. 24 E., Carbon County, Montana.

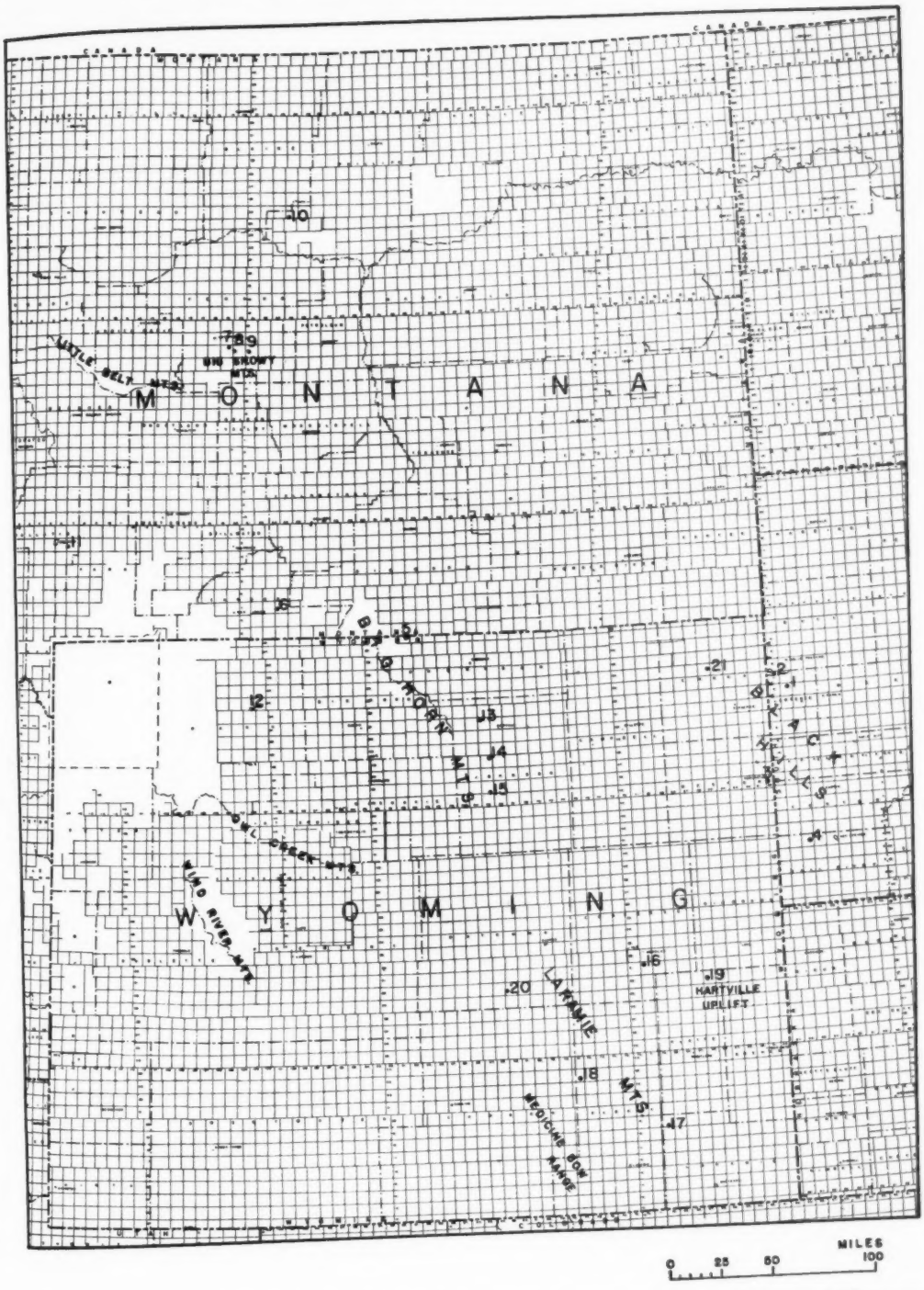


FIG. 1—Index map showing fossil-collecting localities in Wyoming, South Dakota, and Montana. Locality numbers on map correspond to those listed on pp. 156 and 158.

7. Loc. Js-XVII. Swift formation, east side of road, from half a mile to 1 mile north of gypsum factory, sec. 2, T. 14 N., R. 19 E., near Heath, Fergus County, Montana.
8. Loc. Js-XVIII. Rierdon and Swift formations, 1 mile southwest of Piper on northwest corner of the escarpment due east of Bacon ranch, sec. 17, T. 14 N., R. 20 E., Fergus County, Montana.
9. Loc. Js-XIX. Rierdon formation, about 2 miles south of Forest Grove and half a mile east of highway in sec. 16, T. 14 N., R. 21 E., Fergus County, Montana. This section yielded no ostracodes.
10. Loc. Js-XX. Rierdon and Swift formations, 1 mile southwest of Landusky, sec. 32, T. 25 N., R. 24 E., Little Rocky Mountains, Phillips County, Montana.
11. Loc. Js-XXI. Rierdon and Swift formations, on north side of U. S. Highway 10 on north side of Rocky Creek Canyon about 3.7 miles southeast of site of Fort Ellis, or 7 miles southeast of Bozeman court house, sec. 19, T. 2 S., R. 7 E., Gallatin County, Montana (type locality of the Ellis group). This section yielded no ostracodes.
12. Loc. Js-X. "Lower" and "upper Sundance" formations, in gorge of Shoshone River, 2 miles west of Cody, T 53 N., R. 102 W., Park County, Wyoming.

Collections from the following localities were made in August and September, 1950, by the writer and W. C. Vollendorf.

13. Loc. Js-I. Sundance formation, on Tarbert ranch, about 12 miles (map distance) northwest of Buffalo, SE¼ sec. 6, T. 51 N., R. 83 W., Johnson County, Wyoming.
14. Loc. Js-II. Sundance formation, along Dry Muddy Creek, about 14 miles (map distance) south-southwest of Buffalo, S½ sec. 2, T. 48 N., R. 83 W., Johnson County, Wyoming.
15. Loc. Js-III. Sundance formation, on Ramsbottom ranch, north-northeast of Mayoworth, sec. 35, T. 46 N., R. 83 W., Johnson County, Wyoming.
16. Loc. Js-IV. Sundance formation, about 6 miles (map distance) south-southwest of Douglas, on east side of North Platte River, sec. 5, T. 31 N., R. 71 W., Converse County, Wyoming.
17. Loc. Js-V. Sundance formation, about 2 miles (map distance) southwest of Underwood, on northwest side of Chugwater Creek, sec. 34, T. 19 N., R. 70 W., Laramie County, Wyoming. This section yielded no ostracodes.
18. Loc. Js-VI. Sundance formation, about 10 miles (map distance) east of Medicine Bow, half a mile northeast of fish hatchery, sec. 26, T. 23 N., R. 77 W., Albany County, Wyoming.
19. Loc. Js-VII. Sundance formation, at Spanish Diggins, sec. 16 and 21, T. 30 N., R. 66 W., Platte County, Wyoming. This section yielded no ostracodes.

Collections from the following locality were made in September, 1949, by F. M. Swain and the writer.

20. Loc. Js-VIII. Sundance formation, about 2 miles southeast of Alcova, on north side of Bear Springs Creek, sec. 30, T. 30 N., R. 82 W., Natrona County, Wyoming.

Collections were made from the following locality in August, 1951, by the writer.

21. Loc. Js-IX. Stockade Beaver shale member of Sundance formation, 1 mile southwest of Hulett in road cut on east side of highway in SW¼ sec. 12, T. 54 N., R. 65 W., Crook County, Wyoming.

ACKNOWLEDGMENTS

The writer wishes to acknowledge with appreciation the contributions made to this study by A. R. Loeblich, Jr., of the U. S. National Museum, and R. W. Imlay, of the U. S. Geological Survey, who made the sample collections from several of the stratigraphic sections illustrated in this work. Loeblich also prepared the samples and removed specimens from the collections made by him and Imlay. W. D. Quinlivan, of the U. S. Geological Survey, assisted in preparation of the specimens, and W. C. Vollendorf assisted greatly in the field work. Particular thanks are accorded F. M. Swain, of the University of Minnesota, for his generous assistance and valuable criticism during the progress of the work. Financial support for the project was provided in part by the U. S. Geological Survey and in part by the Shell Fellowship Fund at the University of Minnesota.

CONCLUSIONS

Previous studies indicate that the late Paleozoic and the known Mesozoic ostracodes generally are characterized by great differences; but, because of missing information, conclusive statements regarding their relationships cannot yet be made. The lack of published work on early Mesozoic Ostracoda of the United States and the incomplete knowledge concerning the Ostracoda of the upper Paleozoic makes an objective comparison between the two difficult. This is particularly true of the ostracode faunas of the western interior United States, of which only a few Permian species have been described, and none from the Triassic are yet known.

The ancestral relationships of the known western interior Jurassic ostracodes are discussed in a previous paper (Swain and Peterson, 1952). Information gained from the present study has not contributed greatly toward a solution of this problem, although some observations have been made concerning the relationships between the marine Jurassic ostracode assemblages, as indicated below.

From the information now on hand, the following general statements regarding western interior marine Jurassic Ostracoda can be made:

1. The "upper Sundance" and Swift (Oxfordian) ostracode assemblage is distinctly different from the assemblage of the "lower Sundance" and Rierdon (Callovian). Of the 37 species thus far described, a maximum of five are common to both the Callovian and Oxfordian beds (see table 2). The "upper Sundance" and Swift assemblage, however, is closely related to and seems to have stemmed from an assemblage restricted to the "lower Sundance" of central and eastern Wyoming.

2. The ostracodes commonly are more abundant in the silty beds than in the pure shale beds and are rarely found in the sandstone beds. This distribution may be due to conditions of preservation but more probably is related to environmental factors.

3. None of the characteristic Upper Jurassic ostracodes of the Gulf of Mexico region are found in either the Sundance formation or the Ellis group. This fact lends support to the belief that the western interior Jurassic seaways never were directly connected with those of the Gulf region.

4. The "lower Sundance" ostracode assemblage of eastern Wyoming and the Black Hills is markedly different from that of the Rierdon formation in Montana, whereas the succeeding "upper Sundance" and Swift assemblages are mostly similar (see table 2). In connection with these facts, stratigraphic information supports the writer's belief that an active east-trending barrier was present across north-central Wyoming and southeastern Montana during the deposition of the "lower Sundance" and Rierdon sediments. This barrier, referred to as the "Sheridan Arch," was probably structural and evidently was the direct cause of environmental factors that prevented the intermixing of the Rierdon and "lower Sundance" ostracode assemblages. It is interesting to note that, except for the genus *Cytherella*, these two assemblages are completely different, even at the generic level. Apparently the "Sheridan Arch" was ineffective while the greater portion of the "upper Sundance" and Swift deposits were being laid down, a supposition which is supported by the similarity between the ostracode assemblages found in these units. Further information and comment regarding this feature and its relation to distribution of the ostracodes will be presented in a subsequent stratigraphic paper, prepared by the writer for publication in Bulletin of the American Association of Petroleum Geologists.

SYSTEMATIC PALEONTOLOGY

Order OSTRACODA Latreille, 1802

Suborder PLATYCOPA Sars, 1865

Family CYTHERELLIDAE Sars, 1865

Genus CYTHERELLA Jones, 1849

CYTHERELLA PARAMUENSTERI Swain and Peterson, 1952

Plate 17, figures 5–8

Cytherella paramuensteri SWAIN and PETERSON, 1952, U. S. Geol. Survey Prof. Paper 243-A, p. 9, pl. 1, figs. 1–7.

This species is characterized by subquadrate outline, prominent overlap and extension of right valve around entire periphery, inflation of posterior one-fifth of shell in female dimorphs, and presence of a faint, dorsomedian depression and small ventro-

jacent pit; interior of right valve is characterized by a prominent marginal groove, slightly deepened along hinge, and a small, slightly dorsomedian muscle scar consisting of four or five longitudinally elongated marks; inner lamellae and pore canals absent; surface smooth except for numerous very small pits on marginal portions of valves.

Remarks.—Except for its prominent display of sexual dimorphism, this species is strikingly similar to *Cavellina ellipticalis* Hamilton (1942) from the Upper Permian of western Texas. Further studies may show that the two are conspecific.

Length of hypotype (pl. 17, fig. 7) 0.77 mm., height 0.45 mm., thickness 0.31 mm.

Occurrence.—Relatively common to abundant in both the "lower" and the "upper Sundance" formations along the western and southern margins of the Powder River Basin, Wyoming, and in the Rierdon and Swift formations of southern Montana. "Lower Sundance," Loc. Js-I b, d (R to C); Js-II a, b, d (R to C); Js-III b, c, d, e, (C to A); Js-IV h, i, j, (C to A); Js-VIII a, b, c, d, (C to A). Rierdon formation, Loc. Js-XVI h, i (R); Js-XVIII c (LC); Js-XV j (C).

Types.—Hypotype, U.S.N.M. 117884, figured specimens, U.S.N.M. 117882, 117883, 117885.

For a list of additional "upper Sundance" occurrences of this species, see page 156.

CYTHERELLA VENTROPLEURA Swain and Peterson, 1952

Cytherella ventropleura SWAIN and PETERSON, 1952, U. S. Geol. Survey Prof. Paper 243-A, p. 9, pl. 1, figs. 10–12.

Two poorly preserved examples of this species were found in the basal part of the "lower Sundance" formation at locality Js-II.

Occurrence.—"Lower Sundance" formation, Loc. Js-II a (R). (Not figured.)

Genus CYTHERELLOIDEA Alexander, 1929

CYTHERELLOIDEA RECURVATA Peterson, n. sp.

Plate 17, figures 1–4; text-figure 2g

Shell subrectangular in lateral view; greatest height in anterior one-third; dorsal margin nearly straight, slightly arched medially; ventral margin broadly sinuate

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EXPLANATION OF PLATE 17

Retouched photographs of Upper Jurassic ostracodes. For locality descriptions and position in section see pages 156, 158, and table 1.

FIGS. *1–4—Cytherelloidea recurvata* Peterson, n. sp. *1*, Left side (×75) of a paratype (U.S.N.M. 117878). *2*, Right side (×74) of holotype (U.S.N.M. 117879). *3*, *4*, Ventral (×76) and dorsal (×76) views of two paratypes (U.S.N.M. 117880, 117881). All from Rierdon formation, Loc. Js-XV j. (p. 160)

5–8—Cytherella paramuensteri Swain and Peterson, 1952. *5*, Dorsal view (×76) of an immature molt (U.S.N.M. 117882). Rierdon formation Loc. Js-XVIII c. *6*, Left valve interior (×63) (U.S.N.M. 117883). "Lower Sundance" formation, Loc. Js-III c. *7*, Right side (×68) of hypotype (U.S.N.M. 117884). "Lower Sundance" formation, Loc. Js-III c. *8*, Dorsal view (×70) of an internal cast (U.S.N.M. 117885). "Lower Sundance" formation, Loc. Js-III c. (p. 159)

9–11—Orthonotacythere dorsoconvexa Peterson, n. sp. *9*, *10*, Dorsal (×80) and ventral (×80) views of two paratypes (U.S.N.M. 117886, 117887). *11*, Right side view (×80) of holotype (U.S.N.M. 117888). All from Rierdon formation, Loc. Js-XVI k. (p. 164)

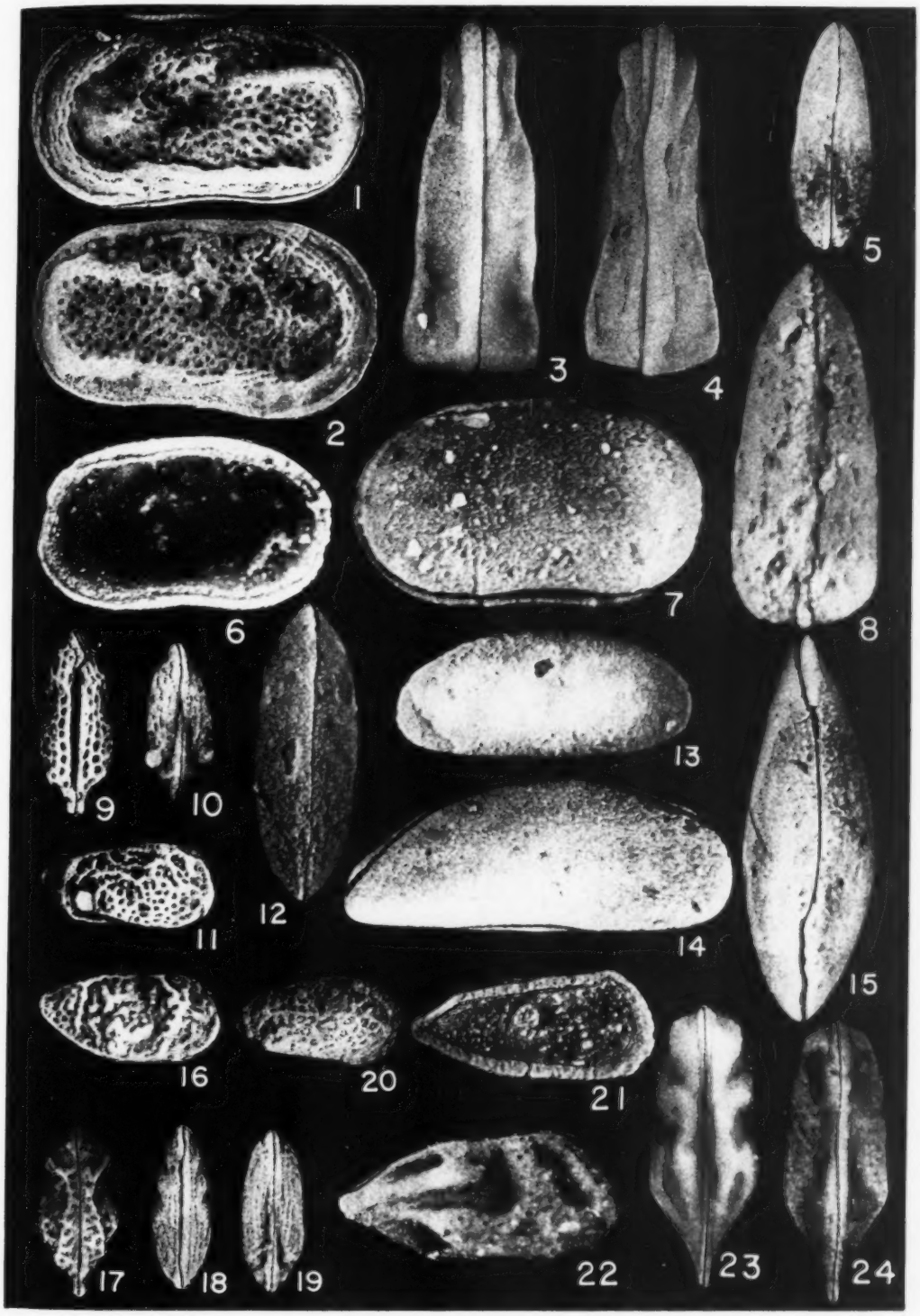
12, *13—Bythocypris jurassica* Peterson, n. sp. *12*, Dorsal view (×67) of a paratype (U.S.N.M. 117889). *13*, Right side (×68) of holotype (U.S.N.M. 117890). Both from Rierdon formation, Loc. Js-XV j. (p. 163)

14, *15—Paracypris projecta* Peterson, n. sp. *14*, Right side (×77) of paratype (U.S.N.M. 117891). *15*, Dorsal view (×77) of holotype (U.S.N.M. 117892). Both from Rierdon formation, Loc. Js-XVI k. (p. 163)

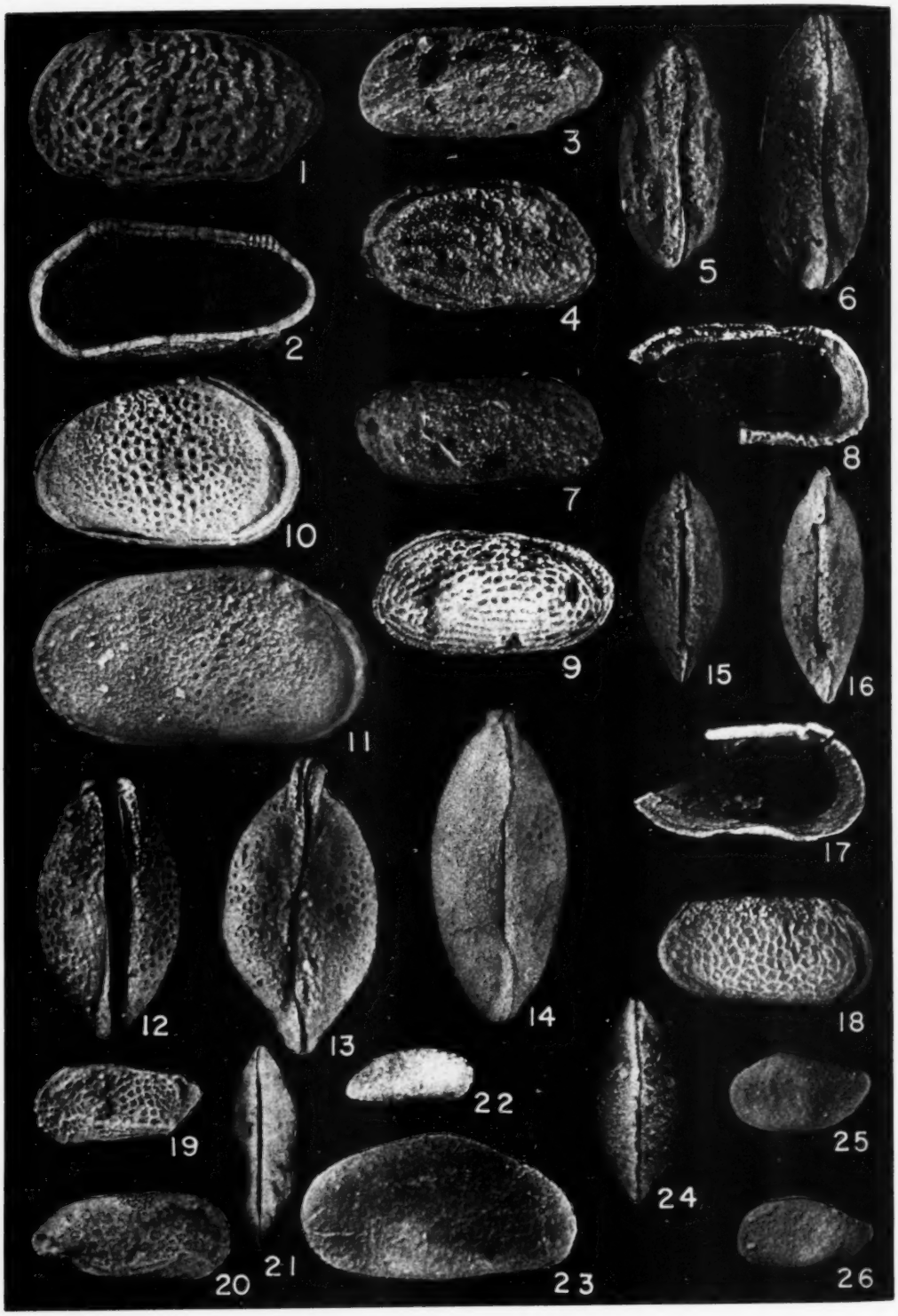
16, *17—Monoceratina incisa* Peterson, n. sp. *16*, Right side (×80) of a paratype (U.S.N.M. 117893). *17*, Dorsal view (×72) of holotype (U.S.N.M. 117894). Both from Rierdon formation, Loc. Js-XVI f. (p. 164)

18–20—Monoceratina sundancensis Swain and Peterson, 1951. Dorsal, ventral, and right side views of hypotype (×77) (U.S.N.M. 117895). Rierdon formation, Loc. Js-XVI h. (p. 165)

21–24—Monoceratina pararossae Peterson, n. sp. *21*, Interior (×68) of a paratype left valve (U.S.N.M. 117896). *22*, *24*, Right side (×74) and ventral view (×74) of two paratypes (U.S.N.M. 117897, 117898). *23*, Dorsal view (×74) of holotype (U.S.N.M. 117899). All from Rierdon formation, Loc. Js-XV j. (p. 165)



Peterson, North American Jurassic Ostracoda



Peterson, North American Jurassic Ostracoda

medially and subparallel to dorsum; anterior margin broadly and uniformly rounded; posterior margin broadly rounded, truncate below midheight.

Right valve larger than left, extending beyond the other around entire periphery, overlapping along dorsal and ventral margins. Shell compressed, particularly in anterior portion; greatest thickness at posterior end.

Anterior end compressed and bearing a narrow, rounded rim. General surface of valves coarsely pitted. A sharp, narrow ridge extends along ventrum and continues around anterior and posterior margins to form an inward-curving or "recurved" peripheral ridge feature. A shallow depression lies just inside anterior portion of marginal ridge. A large, slightly elongate pit, the external expression of the muscle scar, occupies central portion of each valve and is bounded anteriorly by a rounded, obliquely elongate node. A low, irregular ridge pattern lies dorsad of the pit.

Margin of right valve grooved around entire periphery; groove deeper along hinge and upper half of anterior margin. Muscle scar consists of a median prominent elevation upon which are several smaller raised spots.

Length of holotype (pl. 17, fig. 2) 0.70 mm., height 0.41 mm., thickness 0.30 mm.

Relationships.—The present forms are suggestive of *Cytherelloidea leonensis* Howe (1934) from the Gulf Coast Tertiary and *C. weberi* Steghaus (1951) from the Upper Jurassic of Germany. The former, however, is more quadrate in outline, and neither of these species displays the prominent surface pitting characteristic of *C. recurvata.*

Number of specimens examined.—57.

Occurrence.—Relatively rare to abundant in the Rierdon formation, south-central Montana and north-central Wyoming. Loc.

EXPLANATION OF PLATE 18

Retouched photographs of Upper Jurassic ostracodes. For locality descriptions and position in section, see pages 156, 158, and table 1.

FIGS. *1, 2—Progonocythere anoda* Peterson, n. sp. *1,* Left side (×67) of holotype (U.S.N.M. 117900). *2,* Interior (×67) of right valve paratype (U.S.N.M. 117901). Both from Rierdon formation, Loc. Js-XVIII c. (p. 166)

3–5—Protocythere cf. *P. quadricarinata* Swain and Peterson, 1952. *3,* Left side (×70) of hypotype, a female (?) (U.S.N.M. 117902). *5,* Dorsal view (×70) of a female (?) specimen (U.S.N.M. 117903). *4,* Right side of male (?) (×70) (U.S.N.M. 117904). All from "lower Sundance" formation, Loc. Js-II b. (p. 166)

6–9—Protocythere pyriforma Peterson, n. sp. *6,* Dorsal view (×67) of female paratype (U.S.N.M. 117905). *9,* Left side (×64) of holotype, a male (U.S.N.M. 117906). *7, 8,* Right side and left valve interior (×64) of female and male paratypes (U.S.N.M. 117907, 117908). All from "lower Sundance" formation, Loc. Js-II b. (p. 166)

10–14—Aparchitocythere compressa Peterson, n. sp. *10,* Right side (×68) of holotype, a male (U.S.N.M. 117909). *11,* Right side (×65) of female paratype (U.S.N.M. 117910). *12,* Dorsal view (×67) of separated valves of a male paratype (U.S.N.M. 117911). *13, 14,* Dorsal views (×67) of two male paratypes (U.S.N.M. 117912, 117913). All from "lower Sundance" formation, Loc. Js-III b. (p. 168)

15–18—Aparchitocythere elongata Peterson, n. sp. *15, 16,* Dorsal views (×67) of two paratypes (U.S.N.M. 117914, 117915). *17,* Interior (×67) of broken left valve paratype (U.S.N.M. 117916). *18,* Right side (×69) of holotype (U.S.N.M. 117917). All from "lower Sundance" formation, Loc. Js-III b. (p. 168)

19—Eucytherura reticulata Peterson, n. sp. Left side (×67) (figured specimen lost). "Lower Sundance" formation, Loc. Js-III b. (p. 169)

20–21—Paracytheridea polyornata Peterson, n. sp. Right side and dorsal view (×78) of holotype (U.S.N.M. 117919). Rierdon formation, Loc. Js-XVI k. (p. 169)

22—Macrocypris minutus Swain and Peterson, 1952. Right side (×77) (U.S.N.M. 117920). Rierdon formation, Loc. Js-XVI k. (p. 164)

23, 24—Bythocypris ambitruncata Peterson, n. sp. Right side (×67) of holotype (U.S.N.M. 117921) and dorsal view (×67) of a paratype (U.S.N.M. 117922). Both from Rierdon formation, Loc. Js-XVI k. (p. 163)

25—Cytheropteron (*Eocytheropteron*)? *scalpella* Peterson, n. sp. Left side (×67) of holotype (U.S.N.M. 117923). Rierdon formation, Loc. Js-XVI i. (p. 170)

26—Cytheropteron (*Eocytheropteron*)? *lanceolata* Peterson, n. sp. Left side (×67) of holotype (U.S.N.M. 117924). "Lower Sundance" formation, Loc. Js-X k. (p. 170)

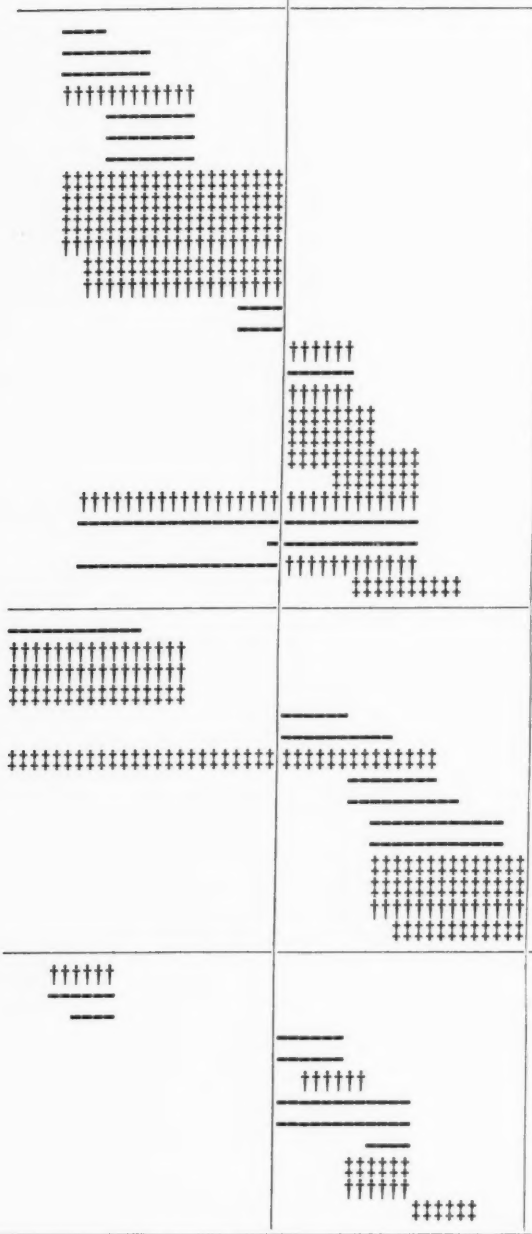


TABLE 2.—Chart showing known stratigraphic range of western interior marine Jurassic Ostracoda. Relative abundance is indicated by the symbols, —, †††, and ‡‡‡ (in order of increasing abundance).

Js-XVI h, i (R to C); Js-XVIII c (LC); Js-XV j (A).

Types.—Holotype, U.S.N.M. 117879; paratypes, U.S.N.M. 117878, 117880, 117881.

Suborder PODOCOPA Sars, 1865
Family BAIRDIIDAE Sars, 1887
Genus BYTHOCYPRIS Brady, 1880
BYTHOCYPRIS JURASSICA Peterson, n. sp.
Plate 17, figures 12, 13

Shell elongate-reniform in side view. Dorsal margin arched, straightened medially; ventral margin nearly straight. Terminal margins broadly rounded, the posterior slightly less than anterior.

Left valve the larger, overlapping and extending beyond the right along dorsal and ventral margins. Valves strongly and evenly convex, greatest thickness median.

Length of holotype (pl. 17, fig. 13) 0.65 mm., height 0.27 mm., thickness 0.24 mm.

Relationships.—This species is similar to *B. gooalandensis* Alexander (1929) from the Lower Cretaceous of Texas, but the latter species is somewhat truncate anteriorly and is characterized by a greater contrast in size between the two valves.

Number of specimens examined.—3.

Occurrence.—Rare in the Rierdon formation, south-central Montana and north-central Wyoming. Loc. Js-XVIII c (R); Js-XV j (R).

Types.—Holotype, U.S.N.M. 117890; paratype, U.S.N.M. 117889.

BYTHOCYPRIS AMBITRUNCATA
Peterson, n. sp.
Plate 18, figures 23, 24

Shell ovate-subreniform in lateral view. Dorsal margin strongly arched, subtruncate posterad and anterad[2] of medially located greatest height; ventral margin nearly straight to slightly convex; anterior margin broadly and evenly rounded; posterior margin less broadly rounded, with slight median truncation in some specimens.

Left valve larger than right, extending beyond it dorsally and ventrally. Valves moderately convex, terminal margins slightly compressed, greatest thickness median. Surface of valves smooth or weakly pitted.

Internal features not observed.

Length of holotype (pl. 18, fig. 23) 0.63 mm., height 0.32 mm., thickness 0.24 mm.

Relationships.—These specimens differ from other representatives of *Bythocypris* in their prominent arching of the dorsal margin and truncation on both sides of the median dorsal point of greatest height.

Number of specimens examined.—4.

Occurrence.—Rare in the Rierdon formation, south-central Montana. Loc. Js-XVI k (R).

Types.—Holotype, U.S.N.M. 117921; paratype, U.S.N.M. 117922.

Family CYPRIDAE Baird, 1846
Genus PARACYPRIS Sars, 1865
PARACYPRIS PROJECTA Peterson, n. sp.
Plate 17, figures 14, 15

Shell elongate in lateral view, highest medially; greatest length ventrad of middle or midheight; dorsal margin strongly arched, ventral margin gently concave; anterior margin broadly and evenly rounded; posterior margin narrowly rounded.

Left valve the larger, extending beyond right along dorsal and ventral margins, overlapping strongly along dorsal slopes and midventrally. Valves moderately convex, greatest thickness just in front of median line. Surface of shell minutely pitted.

Hinge of left valve consists of the simple grooved valve edge, the outer lip of which extends beyond the inner to overlap the intermeshing rabbet-type hinge of right valve. Other internal structures not observed.

Length of holotype (pl. 17, fig. 15) 0.74 mm., height 0.30 mm., thickness 0.26 mm.

Relationships.—The species is somewhat similar to *P. strecca* Schmidt (1948) from the Cretaceous of Maryland, but differs in having a stronger overlap and projection along the dorsal slopes and lesser overlap and extension along central part of dorsum. *P. strecca* also is characterized by a more convex ventrum.

Number of specimens examined.—361.

Occurrence.—Relatively common to abundant in the Rierdon formation, south-central Montana, and in the "lower Sun-

[2] The terms "posterad" and "anterad" indicate "toward the posterior" and "toward the anterior" respectively.

dance" formation in north-central Wyoming. Loc. Js-I b (R); Js-XVI f, h, i, k (C to A); Js-X j, k, o (LC to C); Js-XV j (LC).

Types.—Holotype, U.S.N.M. 117892; paratype, U.S.N.M. 117891.

MACROCYPRIS MINUTUS Swain and Peterson, 1952
Plate 18, figure 22

Macrocypris minutus SWAIN and PETERSON, 1952, U. S. Geol. Survey Prof. Paper 243-A, pp. 9, 10, pl. 1, figs. 13–16.

A single example of this species was found in the upper foot of the Rierdon formation east of Bridger, Montana. It is otherwise known only from the lower two-thirds of the Swift or "upper Sundance" formations.

Occurrence.—Rierdon formation, Loc. Js-XVI k (R).

Figured specimen.—U.S.N.M. 117920.

Family CYTHERIDAE Baird, 1850
Genus ORTHONOTACYTHERE Alexander, 1933
ORTHONOTACYTHERE DORSOCONVEXA Peterson, n. sp.
Plate 17, figures 9–11

Shell subrhomboidal-caudate in outline, greatest height in anterior third; hinge margin convex, about four-fifths of shell length, anterocardinal angle rounded, obtuse, posterocardinal angle undefined because of caudation; ventral margin slightly converging posteriorly toward dorsum, strongly sinuous medially, and making a broadly obtuse posteroventral angle with the bluntly acuminate posterior end; anterior end obliquely truncate above, broadly rounded and slightly extended below.

Valves equal in size. Convexity moderate, greatest thickness about one-fourth distance from posterior end.

Anterior end gently and evenly compressed; posterior end and postero-ventral margin strongly compressed. General valve surface ornamented with an irregular, quasi-reticulate pattern of prominent ridges; a more prominent ridge runs along dorsal margin and curves downward and forward near posterior end of hinge to form a posterodorsal protuberance. A well-defined, rounded tubercle lies just inside posteroventral marginal angle of each valve. Ventral surface swollen and slightly overhanging medially. A broad, faint, vertical sulcus lies just anterad of median line. Valve edges depressed along hinge, forming a deep, narrow furrow as seen in dorsal view of complete shell. Internal details not observed.

Length of holotype (pl. 17, fig. 11) 0.33 mm., height 0.17 mm., thickness 0.16 mm.

Relationships.—The lack of a distinct median vertical sulcus, and the presence of a posteroventral rounded tubercle, rather than a well-defined spine, ally this species more closely with *Orthonotacythere* Alexander than with *Monoceratina* Roth. It differs from described species of both genera in the greater convexity of the hinge margin and the presence of a deep exterior furrow along hinge line, and from most species of *Orthonotacythere* in the marked posteroventral compression. It is here assigned to *Orthonotacythere* with the realization that further study may indicate that it should be referred to a new genus.

Number of specimens examined.—7.

Occurrence.—Rierdon formation, Loc. Js-XVI k (LC).

Types.—Holotype, U.S.N.M. 117888; paratypes, U.S.N.M. 117886, 117887.

Genus MONOCERATINA Roth, 1928
MONOCERATINA INCISA Peterson, n. sp.
Plate 17, figures 16, 17

Shell sublanceolate in lateral view; greatest height near anterior end; hinge margin straight, about three-fourths of shell length; anterocardinal angle obtuse, well defined, posterocardinal angulation lacking; ventral margin convex, converging posteriorly toward dorsum; anterior end broadly rounded, slightly extended below; posterior end acuminate, extended strongly just above midheight.

Valves subequal, the right extending slightly beyond the left only along dorsal margin. Convexity of valves low; greatest thickness just behind middle.

Ends compressed and bearing a faint marginal rim; posterior compression extends along ventral margin for about one-third of shell length. Surface of valves strongly and sharply sculptured. The anteromedian portion of each valve is occupied by a deep, subvertical sulcus, which is bounded anteriorly by a sharp, arcuate ridge and posteriorly by a short, lateral, knife-edged elevation just dorsad of midheight and a conical

spine at the posteroventral valve edge. A narrow, knife-edged ridge extends along the dorsal margin of each valve and curves sharply downward about one-fifth the distance from posterior end. Between ridges, general valve surface finely reticulate.

Internal features not observed.

Length of holotype (pl. 17, fig. 17) 0.36 mm., height 0.19 mm., thickness 0.20 mm.

Relationships.—The distinct median vertical sulcus, ventral spine, posterior caudal extension, and general valve outline ally this species with *Monoceratina* Roth. It is distinguished from other species by the arrangement of knife-edge surface ridge patterns.

Number of specimens examined.—15.

Occurrence.—Rare in the Rierdon formation, south-central Montana and in the "lower Sundance" formation of north-central Wyoming. Loc. Js-XVI f, i (R); Js-X j, k, o (R).

Types.—Holotype, U.S.N.M. 117894; paratype, U.S.N.M. 117893.

MONOCERATINA PARAROSSAE Peterson, n. sp.
Plate 17, figures 21–24

Shell elongate-pentagonal in lateral view, highest near anterior end; hinge margin straight, about two-thirds of shell length; cardinal angles well defined, the anterior slightly obtuse, the posterior broadly obtuse; ventral margin nearly straight and subparallel to dorsum. Anterior margin broadly rounded, slightly extended below and truncate above midheight; posterior end extended medially to form a compressed, sharply acute caudal process.

Left valve slightly larger than right, extending beyond the other along ventral margin and at cardinal slopes. Valve convexity low, greatest along ventrum.

Posterior third and posteroventral region of shell strongly compressed; anteriorly only narrow marginal rim compressed. General surface of valves pitted. A distinct median vertical sulcus divides each valve into two subequal lobes; a rather deep, obliquely elongate sulcus lies adjacent and parallel to anterodorsal margin. Dorsal border of each valve extended, forming a V-shaped groove in dorsal view of complete shell. In posterior half of shell a narrow, slightly oblique, longitudinal ridge lies dorsad of mid-height and extends posteriorly to merge into apex of the caudal extension. Posteroventral border swollen to form a narrow alate extension.

Hinge of left valve, as viewed in one poorly-preserved specimen, consists of the weakly crenulate valve edge with some suggestion of a shallow, elongate socket at its anterior termination.

Length of holotype (pl. 17, fig. 23) 0.57 mm., height 0.28 mm., thickness 0.22 mm.

Relationships.—In general shape and ornamentation this species is somewhat similar to *M. nitida* Alexander (1934) from the Cretaceous of Texas but lacks the prominent ventral spine of the latter. It is more similar to *M. rossae* Alexander (1934), from the Eocene of Texas, differing only in the nature of the surface ridge pattern.

Number of specimens examined.—167.

Occurrence.—Relatively common to abundant in the Rierdon formation, south-central Montana and north-central Wyoming, and in the "lower Sundance" formation in north central Wyoming. Loc. Js-XVI, f, h, i, k (C to A); Js-XVIII c (R); Js-X, j, k, o (LC to C); Js-XV j (A).

Types.—Holotype, U.S.N.M. 117899; paratypes, U.S.N.M. 177896, 117897, 117898.

MONOCERATINA SUNDANCENSIS Swain and Peterson, 1951
Plate 17, figures 18–20

Monoceratina sundancensis SWAIN and PETERSON, 1951, Jour. Paleontology, vol. 25, p. 803, pl. 114, figs. 7–15, text-fig. 1.

This species is characterized by its small size, elongate carapace, reticulate pattern of surface ornamentation, the presence of a median dorsal sulcus, and the subdued nature of the posteroventral marginal swelling.

Length of hypotype (pl. 17, figs. 18–20) 0.32 mm., height 0.16 mm., thickness 0.12 mm.

Occurrence.—Relatively common in both the Rierdon and the Swift formations of central Montana and north-central Wyoming, and in the Redwater member of the Sundance formation in the Black Hills. Rierdon formation, Loc. Js-XVI f, h, i (R to A); Js-XV j (C).

Type.—Hypotype, U.S.N.M. 117895.

For a list of additional "upper Sundance" occurrences of this species, see p. 156.

Genus PROGONOCYTHERE Sylvester-Bradley, 1948

PROGONOCYTHERE ANODA Peterson, n. sp.
Plate 18, figures 1, 2; text-figure 2a

Shell subquadrate in lateral outline, greatest height anterior; hinge margin nearly straight, about two-thirds of shell length; cardinal angles broadly obtuse; ventral margin nearly straight to gently convex, converging slightly posteriorly with dorsum. Anterior margin broadly rounded and slightly extended below, truncate above; posterior margin narrowly rounded, extended below, truncate above; posterior margin narrowly rounded, extended just above midheight.

Left valve the larger, extending beyond the right along lateral margins and slightly overlapping ventrally. Valves strongly inflated ventrally; greatest thickness posteroventral.

Anterior end compressed and bearing a rounded marginal rim; posterior end narrowly compressed to form a short, blunt caudal process. A shallow, oblique sulcus is present just below anterocardinal angle. General surface of valves strongly reticulate.

Hinge of right valve consists of terminal, elongate, crenulate, raised dental areas and the interconnecting weakly crenulate, grooved valve edge. Hinge of left valve consists of corresponding shallow, crenulate sockets and the interterminal narrow, crenulate valve edge. Inner lamellae moderately broad. Radial canals few and widely spaced. Remainder of internal features not observed.

Length of holotype, a left valve (pl. 18, fig. 1), 0.66 mm., height 0.36 mm.

Relationships.—This form is similar to *P. crowcreekensis* Swain and Peterson (1951) in general shape, hingement, and reticulate surface ornamentation. It is distinguished by a strongly expanded ventrum, posteriorly converging lateral margins, and the absence of a prominent anteromedian node

Number of specimens examined.—2.

Occurrence.—Rierdon formation, Loc. Js-XVIII c (R).

Types.—Holotype, U.S.N.M. 117900; paratype, U.S.N M. 117901.

Genus PROTOCYTHERE Triebel, 1938

PROTOCYTHERE PYRIFORMA Peterson, n. sp.
Plate 18, figures 6–9

Shell elongate-subovate, greatest height anterior. Hinge margin slightly convex, about four-fifths of shell length; ventral margin sinuous, subparallel to dorsum. Anterior margin broadly rounded, slightly extended below; posterior margin less broadly but evenly rounded.

Left valve larger than right, overlapping and extending beyond the other, particularly along ventrum. Valves strongly convex in the case of presumed female dimorphs, weakly convex in males; greatest thickness in posterior one-third.

Surface ornamentation uncertain because of condition of preservation, but in some specimens a faint, concentric, reticulate pattern can be observed.

Hinge of left valve as observed in several poorly preserved single valves consists of terminal, elongate, crenulate sockets and an interconnecting bar, dorsad of which lies a shallow accommodation groove. Other internal features not observed.

Length of holotype, male (pl. 18, fig. 9), 0.57 mm., height 0.29 mm., thickness 0.20 mm. Length of female paratype (pl. 18, fig. 6) 0.63 mm., height 0.29 mm., thickness 0.27 mm.

Relationships.—In general outline, hingement, and strong ventral extension of left valve, this species resembles *P. quadricarinata* Swain and Peterson (1952); the latter, however, is more pointed and more extended posteriorly, is terminally compressed, and differs in surface features.

Number of specimens examined.—26.

Occurrence.—Relatively rare to common in the "lower Sundance" formation along the western and southern margins of the Powder River Basin and in the Black Hills. Loc. Js-I b (LC); Js-II a (C); Js-III a, b, c, d, e, (R); Js-IV i (R); Js-VIII c, f (R); Js-IX n, o (R).

Types.—Holotype, U.S.N.M. 117906; paratypes, U.S.N.M. 117905, 117907, 117908.

PROTOCYTHERE cf. P. QUADRICARINATA Swain and Peterson, 1952
Plate 18, figures 3–5

Protocythere quadricarinata SWAIN and PETER-

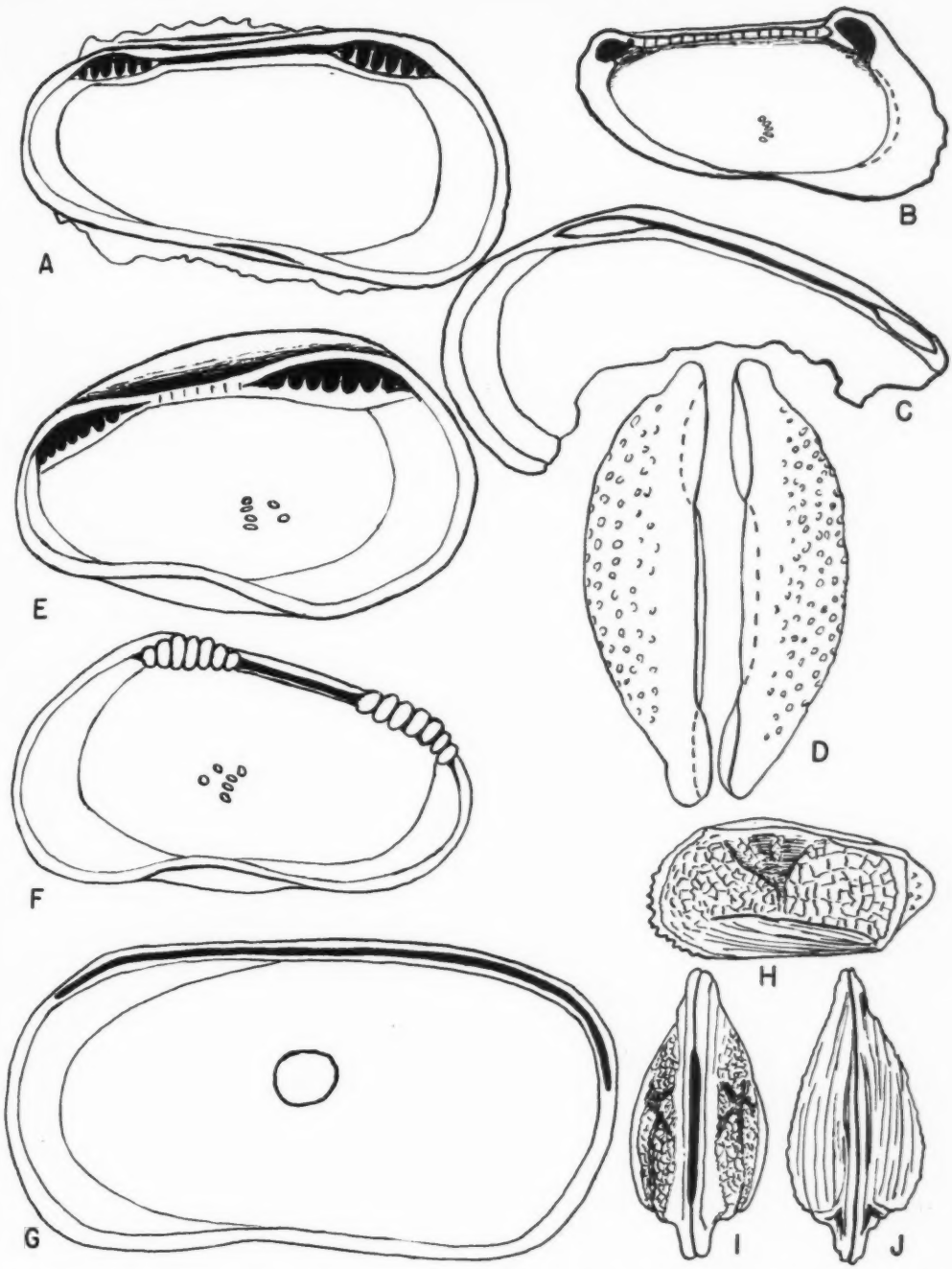


FIG. 2—Camera-lucida drawings of "lower Sundance" ostracodes. A, *Progonocythere anoda*, n. sp., left valve interior (true length 0.64 mm.); B, *Cythereis heteromorpha*, n. sp., left valve interior (0.41 mm.); C, D, *Aparchitocythere compressa*, n. sp., interior of broken right valve (0.58 mm.) and dorsal view of separated valves (0.58 mm.); E, F, *Procytheridea exempla*, n. gen., n. sp., left and right valve interiors (0.51 mm.); G, *Cytherelloidea recurvata*, n. sp., right valve interior (0.68 mm.); H–J, *Cytherura reticulata*, n. sp., left side, dorsal, and ventral views (0.37 mm.).

SON, 1952, U. S. Geol. Survey Prof. Paper 243-A, pp. 13, 14, pl. 2, figs. 14–17, 21.

A few specimens that appear to have the characteristics of this species are found in the lowermost Sundance beds in the western and southwestern parts of the Powder River Basin. Conditions of preservation, however, prevent a definite assignment.

Length of hypotype, a female (pl. 18, fig. 3), 0.52 mm., height 0.24 mm., thickness 0.23 mm.

Occurrence.—"Lower Sundance" formation, Loc. Js-I b (R); Js-II a (R); Js-III c, d (R); Js-VIII c, f (R).

Types.—Hypotype U.S.N.M. 117902, figured specimens 117903, 117904.

Genus APARCHITOCYTHERE Swain and Peterson, 1952

APARCHITOCYTHERE COMPRESSA Peterson, n. sp.

Plate 18, figures 10–14; text-figures 2c, d

Shell subovate to subquadrate in lateral view, greatest height at anterocardinal angle. Dimorphism prominently developed, with males shorter and more ovate than females. Hinge margin nearly straight, about three-fifths of shell length in females, slightly less in males; ventral margin sinuous and subparallel to dorsum in females, slightly convex and converging more strongly toward posterior in males. Anterior margin broadly rounded, slightly extended below; in males, posterior margin more narrowly rounded and extended medially; in females, terminal margins equally rounded, with posterior extended slightly above median.

Left valve larger than right, overlapping and extending beyond the other except along hinge, where right valve overlaps and extends prominently beyond left. Valves strongly convex; greatest thickness just postmedian. Anterior end strongly compressed and bearing a prominent marginal rim; posterior end less strongly compressed and bearing an obscure marginal rim in males. Surface ornamentation ranges from coarse, prominent pitting to very weak, fine pitting, with the latter particularly characteristic of adult specimens.

Hinge of left valve consists of terminal, elongate sockets that are emphasized by the overlapping dorsal slopes in this valve, and an interconnecting narrow bar with dorsojacent groove. Hinge of right valve consists of terminal elongate teeth, formed of the extended valve edge, and an inter-terminal narrow groove. Inner lamellae moderately broad, sloping steeply toward interior. Radial canals few and widely spaced. Muscle scar consists of median subvertical row of four small spots and two more anterior spots.

Length of holotype, a male (pl. 18, fig. 10), 0.59 mm., height 0.40 mm., thickness 0.33 mm. Length of female paratype (pl. 18, fig. 11) 0.79 mm., height 0.42 mm., thickness 0.34 mm.

Relationships.—In general outline, valve relationships, and hingement this species is related to *A. typica* Swain and Peterson (1952), but the latter has a much more inflated appearance and lacks the prominent pitting and strong terminal compression characteristic of the present species.

Number of specimens examined.—140.

Occurrence.—Relatively common to abundant in the "lower Sundance" formation along the western and southern margins of the Powder River Basin, Wyoming, and in the Black Hills. Loc. Js-I b, d (LC); Js-II a (A); Js-III a, b, c, d, e (A); Js-IV j (R); Js-VII a, b, c, d, e, f (LC) Js-IX k, m. n, o (R to C).

Types.—Holotype, U.S.N.M. 117909; paratypes, U.S.N.M. 117910, 117911, 117912, 117913.

APARCHITOCYTHERE ELONGATA Peterson, n. sp.

Plate 18, figures 15–18

Shell small, elongate-subovate to subrectangular in outline, greatest height anterior. Hinge margin straight, about four-fifths of shell length; ventral margin sinuous subparallel to dorsum. Anterior margin broadly rounded, slightly extended below; posterior margin subtruncate, extended submedially.

Left valve slightly larger than right, overlapping and extending beyond the other, particularly along hinge line. Valves moderately convex; greatest thickness just behind middle.

Anterior end compressed and bearing a narrow, rounded marginal rim; posterior end gently compressed. Surface ornamentation

consists of a weak, heterogeneous ridge pattern that in part becomes longitudinal near ventral border. In most specimens a shallow, subvertical sulcus lies just anterad of median line and is expressed internally by a weak ridge lying just posterior to muscle scar.

Hinge of left valve consists of narrow, elongate, terminal sockets and intervening narrow bar. Hinge of right valve consists of terminal, elongate teeth, formed of the extended valve edge, and an interterminal narrow groove. Inner lamellae broad, sloping steeply toward interior. Inner margin and line of concrescence slightly separated. Pore canals not observed. Muscle scar consists of a subvertical, crescent-shaped row of four small spots and two more anterior spots.

Length of holotype (pl. 18, fig. 18) 0.48 mm., height 0.24 mm., thickness 0.20 mm.

Relationships.—This form differs from other known species of *Aparchitocythere* in its smaller size, more rectangular shape, and better developed surface ornamentation. In other respects it has the features characteristic of the genus.

Number of specimens examined.—21.

Occurrence.—Relatively common in the "lower Sundance" formation along the western and southern borders of the Powder River Basin and in the Black Hills. Loc. Js-I b, d (R); Js-II a (LC); Js-III a, b, c (C); Js-IV j (R); Js-VIII c (R); Js-IX k (R).

Types.—Holotype, U.S.N.M. 117917; paratypes, U.S.N.M. 117914, 117915, 117916.

Genus EUCYTHERURA Müller, 1894

EUCYTHERURA RETICULATA Peterson, n. sp.

Plate 18, figure 19; text-figures 2h, i, j

Shell small, subrhomboid in lateral view; greatest height anterior, greatest length median. Dorsal margin gently arched, about four-fifths of shell length; ventral margin nearly straight, converging posteriorly toward dorsum. Anterior end extended medially, truncate above and below; posterior end bluntly acuminate, extended just above middle.

Valves subequal, the right slightly larger and extending beyond the other along dorsal margin, the left overlapping along ventral margin. Valves compressed in anterior half; greatest thickness in posteroventral one-third.

Anterior end spinose, compressed, and bearing a faint marginal rim; posterior end compressed to form a blunt, caudate extension. Valve surfaces somewhat swollen in a narrow area just below anterocardinal angle. A shallow, vertical sulcus lies at mid-length of each valve. Posteroventral valve edges occupied by prominent winglike expansions. General surface weakly reticulate, with longitudinal elements of reticulation becoming more prominent along dorsal and ventral margins.

Hinge structure, as observed in one poorly preserved right value, includes terminal tooth elements separated by a minutely crenulate interterminal groove; details of these features uncertain because of condition of preservation. Other internal features not observed.

Length of figured specimen (pl. 18, fig. 19) 0.38 mm., height 0.19 mm., thickness 0.20 mm.

Relationships.—In general shape, complex surface ornamentation, presence of anterior marginal spines, and crenulate interterminal hinge feature, this species conforms to *Eucytherura* Müller (1894). It is somewhat similar to *E. murdercreekensis* Howe and Law (1936) from the Gulf Coast Tertiary but differs in having a convex dorsal margin, a more upturned posterior caudal process, and a reticulate (rather than pitted) general surface ornamentation.

Number of specimens examined.—3.

Occurrence.—Rare in the lowermost Sundance beds along the Big Horn Mountains, Wyoming. Loc. Js-II a (R); Js-III b (R).

Type.—Holotype, right valve, not figured, U.S.N.M. 117918.

Genus PARACYTHERIDEA Müller, 1894

PARACYTHERIDEA POLYORNATA Peterson, n. sp.

Plate 18, figures 20, 21

Shell small, elongate-subquadrate, highest near anterior end, greatest length median; dorsal margin nearly straight, about four-fifths of shell length; cardinal angles obtuse, the posterior better defined; ventral margin slightly concave, converging posteriorly with dorsum; anterior margin broadly and evenly rounded, slightly extended below;

posterior margin narrowly rounded, strongly extended medially.

Right valve slightly larger, extending beyond the left along dorsum. Convexity of valves low, greatest thickness in posterior half.

Ornamentation consists of a polygonal, reticulate pattern of low ridges over the general shell surface, with the longitudinal elements of reticula becoming more prominent in ventral region. Surface between ridges occupied by rounded, very fine nodes. Ventral surface of each valve expanded laterally to form prominent overhanging posteroventral alae.

Internal features not observed.

Length of holotype (pl. 18, fig. 20) 0.38 mm., height 0.18 mm., thickness 0.16 mm.

Relationships.—In some respects, the present species is similar to species of *Paracytheridea* Müller in the Tertiary of the Gulf and Atlantic coasts. In general shape it is closely similar to *P. mucra* Edwards (1944), but differs in having a shorter and more blunt ventral overhang and a less sharply compressed posterior extension. It is distinguished by the polygonal nature of the surface ornamentation pattern.

Number of specimens examined.—4.

Occurrence.—Rare in Rierdon formation, Loc. Js-XVI h (R); Js-XVIII c (R); Js-XV j (R).

Types.—Holotype, U.S.N.M. 117919.

Genus CYTHEROPTERON Sars, 1865
Subgenus EOCYTHEROPTERON Alexander, 1933
CYTHEROPTERON (EOCYTHEROPTERON)?
LANCEOLATA Peterson, n. sp.
Plate 18, figure 26

Shell small, sublanceolate in lateral view; greatest height two-fifths distance from anterior. Dorsal margin arched, ventral margin slightly sinuous. Anterior end broadly rounded, subtruncate above; posterior end acutely caudate.

Valves subequal, the right extending beyond the left along dorsum. Convexity medium, greatest thickness median.

Compression of posterior caudal process extends along ventrum, forming a sharp ridge as seen in ventral view of complete shell. Median ventral surface of each valve swollen. General surface of valves finely pustulose.

Internal features not observed.

Length of holotype (pl. 18, fig. 26) 0.30 mm., height 0.16 mm., thickness 0.16 mm.

Relationships.—This species is distinguished from *C.* (*E.*)*.? scalpella*, n. sp., by its sublanceolate outline, more prominent ventral swelling, and less strongly upturned caudal process.

Number of specimens examined.—1.

Occurrence.—"Lower Sundance" formation, Loc. Js-X k (R).

Type.—Holotype, U.S.N.M. 117924.

CYTHEROPTERON (EOCYTHEROPTERON)?
SCALPELLA Peterson, n. sp.
Plate 18, figure 25

Shell small, ovate in lateral view; greatest height one-third distance from anterior. Dorsal margin strongly arched, truncate; ventral margin nearly straight. Anterior end broadly and evenly rounded; posterior end produced into an acute, upward-curving caudal process.

Valves subequal, the right slightly larger and extending beyond the other along dorsal margin. Convexity strong, greatest thickness median.

Anterior end gently compressed; posteroventral margin and posterior caudal process strongly compressed. Median ventral surface of each value slightly expanded into a broad, even swelling. General valve surface minutely pustulose.

Internal features not observed.

Length of holotype (pl. 18, fig. 25) 0.33 mm., height 0.19 mm., thickness 0.18 mm.

Relationships.—The present specimens are provisionally assigned to *Eocytheropteron* Alexander, 1933. They differ from representatives of described species of the subgenus in having a less prominent ventral inflation, a larger and less compressed posterior caudate extension, and the right valve slightly larger than the left. When earlier Mesozoic Ostracoda are better understood, these forms may prove to be representatives of a genus ancestral to *Cytheropteron*, which is common in the Cretaceous and Tertiary of the Gulf Coast.

Number of specimens examined.—2.

Occurrence.—Rierdon formation, Loc. Js-XVI i (R). Holotype, U.S.N.M. 117923.

Genus PROCYTHERIDEA Peterson, n. gen.

Shell ovate to subtriangular-ovate; hinge margin straight to slightly arched, converging toward ventrum; ventral margin sinuous, usually turned inward medially. Anterior margin broadly rounded, slightly extended below, truncate above; posterior margin narrowly rounded, more or less extended medially. Left valve larger than right, and overlapping along ventrum and dorsal slopes. Surface moderately to strongly reticulate, with longitudinal elements of reticulum frequently developed into ridges; median valve surface on some specimens tends to be flattened or slightly undulating.

Hinge of left valve consists of terminal elongate, elliptical, notched sockets separated by a narrow to moderately heavy bar, dorsal to which lies an accommodation shelf or groove. In many specimens hinge bar is terminally split into two narrow bars by extensions of sockets. Hinge of right valve consists of corresponding terminal, toothed dental areas, and an interterminal weakly crenulate groove. Inner lamellae broad; line of concrescence and inner margin nearly coincide. Muscle scar consists of a median subvertical row of four spots and a cluster of two or three more-anterior spots. Dimorphism typically occurs and is characterized by larger, more elongate females.

Type species.—*Procytheridea exempla* Peterson, n. sp.

Geologic range.—The present known range is the Callovian stage of the Upper Jurassic. Perhaps the Cretaceous form described as *Cytheridea canadensis* Scott (1947) should be referred to this genus.

Relationships.—The nature of hingement, valve relationships, and muscle pattern ally this genus with members of *Cytheridea* Bosquet, particularly the subgenus *Haplocytheridea* Stephenson. The latter, however, is characterized by a more complex hingement and also differs markedly from *Procytheridea*, n. gen., in surface ornamentation. It seems reasonable to suppose that the present genus is indirectly related to some genus in the ancestral stock of the Gulf Coast *Cytheridea*, e.g., the Jurassic genus *Schuleridea* Swartz and Swain. The hinge characteristics of the latter genus are suggestive of *Procytheridea*, n. gen., although in external features the two are much different.

In valve relationships, presence of a strong accommodation groove, and particularly in hingement, the specimens here placed in *Procytheridea* are suggestive of *Protocythere* Triebel. The latter, however, differs in surface features, is generally more elongate, and does not display the prominent dimorphism of the present genus.

PROCYTHERIDEA EXEMPLA Peterson, n. sp.
Plate 19, figures 6–14; text-figure 2, e, f

Shell subtriangular in side view; hinge margin slightly convex, about three-fifths of shell length; cardinal angles broadly obtuse, the posterior better defined; ventral margin nearly straight, converging strongly toward posterior with respect to dorsum; anterior margin broadly rounded, slightly extended below, subtruncate above; posterior margin narrowly rounded, extended medially.

Left valve much larger than right, extending beyond the other; greatest extension along dorsal and ventral margins, overlapping along ventral margin. Valves moderately convex, greatest thickness in posterior half of shell.

Ends compressed and bearing a narrow marginal rim; posterior end slightly extended medially. Surface ornamented with a reticulate pattern which is more or less concentric but discontinuous in the outer region of the shell, but grades centrally into a more longitudinally arranged pattern. A shallow sulcus, directed obliquely forward, lies near anterodorsal angle; posterodorsal surface of each valve produced to form a short, prominent, oblique ridge bounded dorsally by a broad, shallow sulcus. Anteroventral surface somewhat swollen, giving a slightly alate appearance to the shell.

Hinge of left valve consists of terminal, elongate, elliptical, denticulate sockets opening terminally into valve interior and connected by a short, weakly crenulate, narrow bar; a well-developed, broad, rather deep accommodation groove, about two-thirds of hinge length, lies dorsad of hinge bar. Hinge of right valve consists of elongate, crenulate, elevated terminal dental areas and the intervening valve edge, which bears a weakly crenulate groove.

Inner lamellae broad, sloping steeply toward interior in left valve, somewhat less

steeply in right. Line of concrescence and inner margin nearly coincide. Pore canals not observed. Muscle scar consists of a subvertical row of four spots, slightly anterad of midlength, and two more anterior spots.

Presumed male dimorphs are shorter, more triangular in outline and somewhat more prominently ornamented; females are elongate and more evenly convex. Male forms tend to be somewhat flattened centrally and have a much more prominent accommodation groove.

Length of holotype, a male (pl. 19, fig. 6), 0.54 mm., height 0.32 mm., thickness 0.28 mm. Length of a female paratype (pl. 19, fig. 10) 0.58 mm., height 0.32 mm., thickness 0.28 mm.

Relationships.—The subtriangular shape and strong development of an accommodation groove, particularly in the males, serve to distinguish this species.

Number of specimens examined.—872.

Occurrence.—Abundant to very abundant in the Rierdon formation, south-central Montana, and in the "lower Sundance" formation in north-central Wyoming. Loc. Js-XVI f, h, i, k (VA); Js-XVIII c (VA); Js-X j k, o (A); Js-XV j (VA).

Types.—Holotype, U.S.N.M. 117930; paratypes, U.S.N.M. 117931, 117932, 117933, 117934, 117935, 117936, 117937, 108599.

PROCYTHERIDEA CRASSA Peterson, n. sp.
Plate 19, figures 1–5

Shell subelliptical in lateral view. Dimorphism prominently exhibited, with males shorter and more ovate than females. Hinge margin nearly straight, about three-fifths of shell length, cardinal angles broadly obtuse, the posterior better defined; ventral margin nearly straight, subparallel to dorsum, slightly concave medially. Anterior margin broadly rounded, extended below and subtruncate above; posterior margin more narrowly rounded, slightly extended medially.

Left valve larger than right, extending beyond the other along dorsal margin and cardinal slopes and slightly overlapping along median ventral margin. Convexity pronounced, relatively uniform over shell surface, except for slight ventral overhang; greatest thickness in posterior third of shell.

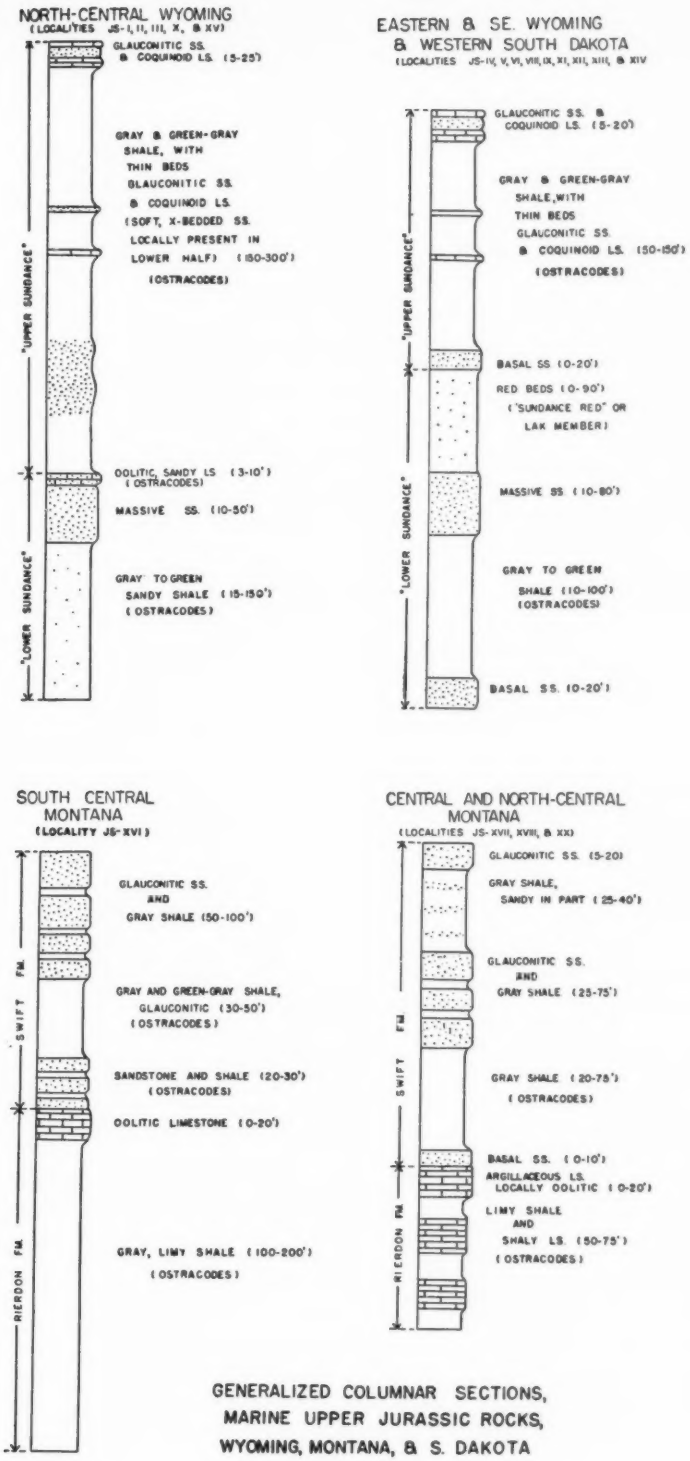
Anterior end of shell compressed and bearing a narrow marginal rim; median extension of posterior end compressed to form a narrow, slightly caudate process. Surface ornamentation in general is coarsely and randomly reticulate, but passes into longitudinal ridges along the ventral overhang of the carapace. Shell wall thick.

Hinge of left valve consists of terminal, elongate, denticulate sockets connected by a very weakly crenulate narrow bar, which is bounded dorsally by an accommodation shelf, rather shallow in the case of female specimens, but better defined in males. Hinge of right valve consists of terminal, elongate, crenulate, elevated dental processes and the interterminal, faintly crenulate, extended rabbet-edge of valve.

Inner lamellae broad, sloping gently inward; line of concrescence and inner margin nearly coincide. Muscle scar and pore canals not observed.

Length of female paratype (pl. 19, fig. 3) 0.66 mm., height 0.36 mm., thickness 0.37 mm. Length of holotype, a male (pl. 19, fig. 2), 0.57 mm., height 0.36 mm., thickness 0.34 mm.

Relationships.—*Cytheridea canadensis* Scott (1947) resembles the present species in general shape and hingement but is more pointed posteriorly and has fewer crenulations on the terminal hinge elements. The left valve hinge of Scott's specimens also has an interterminal double ridge separated by a narrow groove, in contrast to the single interterminal ridge of *P. crassa*, n. sp. Species of *Klieana* Martin (1940) are similar in hingement to the present species but are characterized by a ventral alation (rather than an even swelling) and have narrower inner lamellae. Representatives of *Macrodentina* Martin (1940) are similar in shape and surface ornamentation but differ in the nature of their hinge features. Specimens referred to *Macrodentina* sp. cf. *M. lineata* Martin by Brand (1949, pl. 6) conform in external characteristics to the present specimens, but the differences in hingement prevent an assignment to that genus. The hingement of *Macrodentina lineata* Martin 1940 has recently been redescribed by Steghaus (1951), who assigns the species to *Clithrocytheridea* Stephenson. Steghaus' de-


NORTH-CENTRAL WYOMING
(LOCALITIES JS-I, II, III, X, & XV)
GLAUCONITIC SS. & COQUINOID LS. (5-25')
GRAY & GREEN-GRAY SHALE, WITH THIN BEDS GLAUCONITIC SS. & COQUINOID LS. (SOFT, X-BEDDED SS. LOCALLY PRESENT IN LOWER HALF) (150-300')
(OSTRACODES)
OOLITIC, SANDY LS (3-10') (OSTRACODES)
MASSIVE SS. (10-50')
GRAY TO GREEN SANDY SHALE (15-150') (OSTRACODES)
"UPPER SUNDANCE"
"LOWER SUNDANCE"
EASTERN & SE. WYOMING & WESTERN SOUTH DAKOTA
(LOCALITIES JS-IV, V, VI, VII, IX, XI, XII, XIII, & XIV
GLAUCONITIC SS. & COQUINOID LS. (5-20')
GRAY & GREEN-GRAY SHALE, WITH THIN BEDS GLAUCONITIC SS. & COQUINOID LS. (50-150')
(OSTRACODES)
BASAL SS (0-20')
RED BEDS (0-90') ("SUNDANCE RED" OR LAK MEMBER)
MASSIVE SS. (10-80')
GRAY TO GREEN SHALE (10-100') (OSTRACODES)
BASAL SS. (10-20')
"UPPER SUNDANCE"
"LOWER SUNDANCE"
SOUTH CENTRAL MONTANA
(LOCALITY JS-XVI)
GLAUCONITIC SS. AND GRAY SHALE (50-100')
GRAY AND GREEN-GRAY SHALE, GLAUCONITIC (30-50') (OSTRACODES)
SANDSTONE AND SHALE (20-30') (OSTRACODES)
OOLITIC LIMESTONE (0-20')
GRAY, LIMY SHALE (100-200') (OSTRACODES)
SWIFT FM.
RIERDON FM.
CENTRAL AND NORTH-CENTRAL MONTANA
(LOCALITIES JS-XVII, XVIII, & XX)
GLAUCONITIC SS. (5-20)
GRAY SHALE, SANDY IN PART (25-40')
GLAUCONITIC SS. AND GRAY SHALE (25-75')
GRAY SHALE (20-75') (OSTRACODES)
BASAL SS. (0-10')
ARGILLACEOUS LS. LOCALLY OOLITIC (0-20')
LIMY SHALE AND SHALY LS. (50-75') (OSTRACODES)
SWIFT FM.
RIERDON FM.

GENERALIZED COLUMNAR SECTIONS,
MARINE UPPER JURASSIC ROCKS,
WYOMING, MONTANA, & S. DAKOTA

FIG. 3

scription serves to ally *Procytheridea crassa*, n. sp., more closely with Martin's species, but the latter lacks the elliptical terminal hinge elements of the former and differs also in valve relationships and complexity of surface ornamentation.

Number of specimens examined.—307.

Occurrence.—Relatively common to abundant in the Rierdon formation, south-central Montana, and in the "lower Sundance" formation in north-central Wyoming. Loc. Js-XVI f, h, i, k (LC); Js-XVIII c (VA); Js-X j, k, o (LC); Js-XV j (C).

Types.—Holotype, U.S.N.M. 117927; paratypes, U.S.N.M. 117925, 117926, 117928, 117929.

PROCYTHERIDEA MINUTA Peterson, n. sp.
Plate 19, figures 15–19

Shell small, elongate-ovate in lateral view; highest near anterior end; hinge margin nearly straight, about two-thirds of shell length, cardinal angles broadly obtuse; ventral margin straight and subparallel to but slightly convergent with dorsum toward posterior; anterior margin broadly and obliquely rounded, subtruncate above; posterior margin narrowly rounded, extended medially.

Left valve larger than right, extending beyond the other along lateral margins, overlapping along cardinal slopes and median ventral margin; valves not strongly convex, greatest thickness near posterior end.

Posterior end strongly compressed and bearing a low, rounded marginal rim; anterior end slightly compressed and provided with a narrow marginal rim. General surface of valves ornamented by prominent lateral ridges, which in part tend to merge near valve ends; spaces between ridges finely reticulate.

Hinge of left valve consists of terminal, elongate, denticulate sockets separated by a weakly crenulate bar formed of the extended valve edge; dorsad of hinge bar lies a broad, shallow accommodation groove. Hinge of right valve consists of terminal, elongate, crenulate teeth and an interterminal, well-defined, weakly crenulate groove.

Muscle scar and other internal features not observed.

Dimorphism exhibited by the greater elongation of presumed females.

Length of holotype, a male (pl. 19, fig. 16), 0.36 mm., height 0.20 mm., thickness 0.17 mm. Length of female paratype (pl. 19, fig. 19) 0.44 mm., height 0.22 mm., thickness 0.20 mm.

Relationships.—In hingement, valve relationships, and general shape this species is similar to *P. exempla*, n. sp., but its smaller size, less prominent accommodation groove, and stronger longitudinal elements in the surface ornamentation prevent an assignment to that species.

Number of specimens examined.—48.

Occurrence.—Relatively common in the Rierdon formation, south-central Montana, Loc. Js-XVI k (C); Js-XVIII c (A).

Types.—Holotype, U.S.N.M. 108602; paratypes, U.S.N.M. 108600, 108601, 108603, 108604.

Genus CYTHEREIS Jones, 1849

CYTHEREIS HETEROMORPHA Peterson, n. sp.
Plate 19, figures 20–24; text-figure 2 b

Shell small, subquadrate in outline; greatest height near anterior end, greatest length median; dorsal margin straight, about four-fifths of shell length; cardinal angles obtuse, subequal, well defined; ventral margin nearly straight, converging posteriorly toward dorsum; anterior end broadly rounded, slightly extended below; posterior end bluntly acuminate, extended medially.

Valves subequal, the left extending slightly beyond the right only at cardinal angles. Convexity moderate, greatest thickness in posterior half.

Posterior end compressed and bearing a faint marginal rim. Anterior end slightly compressed and provided with a rounded marginal rim; compression more pronounced in upper half; lower half weakly denticulate. A low, rounded node lies near anterodorsal angle and passes downward into a well-defined, irregular ridge. A similar ornamentation feature lies just anterad of posterocardinal margin. In most specimens two small, rounded, separated nodes lie near median dorsal margin. Posteroventral margin is occupied by a small, rather blunt protuberance. Two or three low, oblique or

longitudinal ridges are present on lower half of shell. Surface of shell between ridges reticulate. The species is characterized by considerable variation in surface ornamentation, particularly with respect to strength of the longitudinal elements.

Hinge of left valve consists of terminal sockets, which open ventrally into valve interior, and a long, faintly crenulate interterminal bar. In some specimens there is a suggestion of a small rounded tooth postjacent to anterior socket. Hinge of right valve consists of an anterior small, rounded tooth, a more elongate, rounded posterior tooth, and an interterminal weakly crenulate groove. Inner lamellae broad, sloping steeply toward valve interior. Line of concrescence and inner margin nearly coincide. Muscle scar consists of an arcuate row of four or five spots situated at midlength and at least one more anterior spot. Pore canals not observed.

Length of holotype (pl. 19, fig. 24) 0.32 mm., height 0.20 mm., thickness 0.16 mm.

Relationships.—The species is similar in ornamentation and general shape to one illustrated by Brand (1949, pl. X) as "ostracode 80" from the Middle Jurassic (Dogger) of Germany. The general shape, cardinal overlap, general hinge features, and surface ornamentation ally the present species with *Cythereis*, but the hingement is not so well developed as in typical species. *C. heteromorpha*, n. sp., along with *C. zygoventralis* Swain and Peterson (1952), from the Redwater shale member of the Sundance formation may represent a new genus.

Number of specimens examined.—271.

Occurrence.—Relatively common to abundant in the Rierdon formation, south-central Montana, and in the "lower Sundance" formation in north-central Wyoming. Loc. Js-XVI f, h, i, k (C to A); Js-XVIII c (R); Js-X j, k, o (A); Js-XV j (A).

Types.—Holotype, U.S.N.M. 108609; paratypes, U.S.N.M. 108605, 108606, 108607, 108608.

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EXPLANATION OF PLATE 19

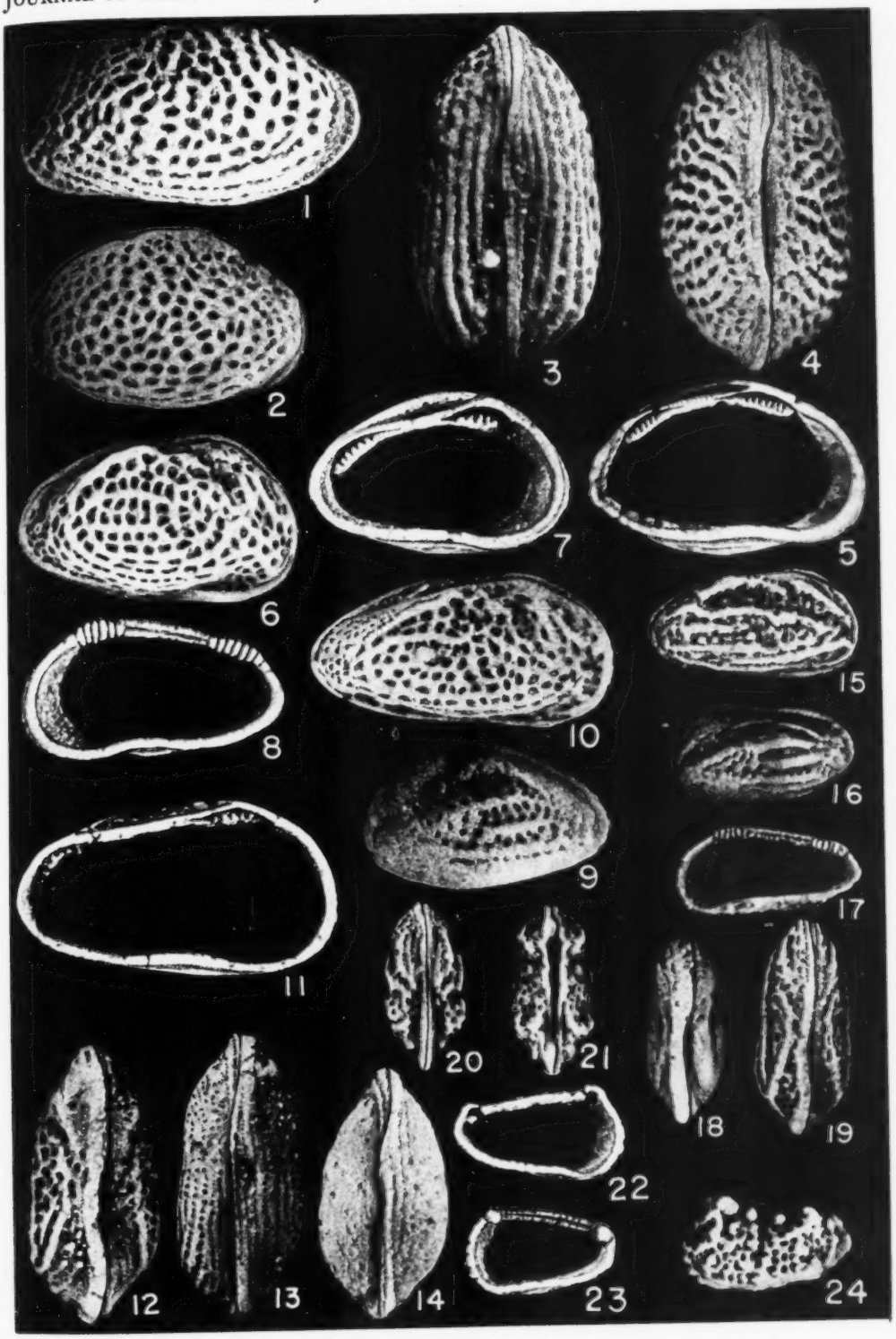
Retouched photographs of Upper Jurassic ostracodes. For locality descriptions and position in section, see pages 156, 158 and table 1.

FIGS. *1–5—Procytheridea crassa* Peterson, n. sp. *1, 4,* Left side and dorsal view of two female paratypes (×79) (U.S.N.M. 117925, 117926). *2,* Right side (×76) of holotype, a male (U.S.N.M. 117927). *3,* Ventral view (×79) of female paratype (U.S.N.M. 117928). *5,* Interior (×82) of left valve of a male paratype (U.S.N.M. 117929). All from Rierdon formation, Loc. Js-XVIII c. (p. 172)

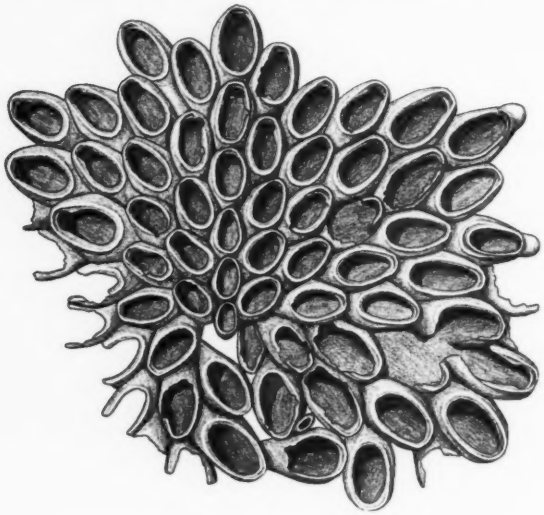
6–14—Procytheridea exempla Peterson, n. sp. *6,* Right side (×77) of holotype, a male (U.S.N.M. 117930). Rierdon formation, Loc. Js-XV j. *7, 8, 9, 14,* Left and right valve interiors, left side, and ventral views of four male paratypes (×77) (U.S.N.M. 117931, 117932, 117933, 117934). Rierdon formation, Loc. Js-XV j. *10, 11, 13,* Right side, left valve interior, and ventral view (×77) of three female paratypes (U.S.N.M. 117935, 117936, 117937). Rierdon formation, Loc. Js-XVIII c. *12,* Dorsal view of a male paratype (×77) (U.S.N.M. 108599). Rierdon formation, Loc. Js-XVIII c. (p. 171)

15–19—Procytheridea minuta Peterson, n. sp. *15, 17,* Right side (×77) and right valve interior (×67) of two female paratypes (U.S.N.M. 108600, 108601). Rierdon formation, Loc. Js-XVIII c. *16,* Left side (×77) of holotype, a male (U.S.N.M. 108602). Rierdon formation, Loc. Js-XVI k. *18,* Dorsal view (×77) of a male paratype (U.S.N.M. 108603). Rierdon formation, Loc. Js-XVI k. *19,* Dorsal view (×73) of female paratype (U.S.N.M. 108604). Rierdon formation, Loc. Js-XVIII c. (p. 174)

20–24—Cythereis heteromorpha Peterson, n. sp. *20, 21,* Ventral and dorsal views of two paratypes (×80) (U.S.N.M. 108605, 108606). Rierdon formation, Loc. Js-XV j. *22,* Left valve interior of a paratype (×70) (U.S.N.M. 108607). Rierdon formation, Loc. Js-XVI k. *23,* Right valve interior of a paratype (×80) (U.S.N.M. 108608). Rierdon formation, Loc. Js-XV j. *24,* Left side (×77) of holotype (U.S.N.M. 108609). Rierdon formation, Loc. Js-XV j. (p. 174)



Peterson, North American Jurassic Ostracoda



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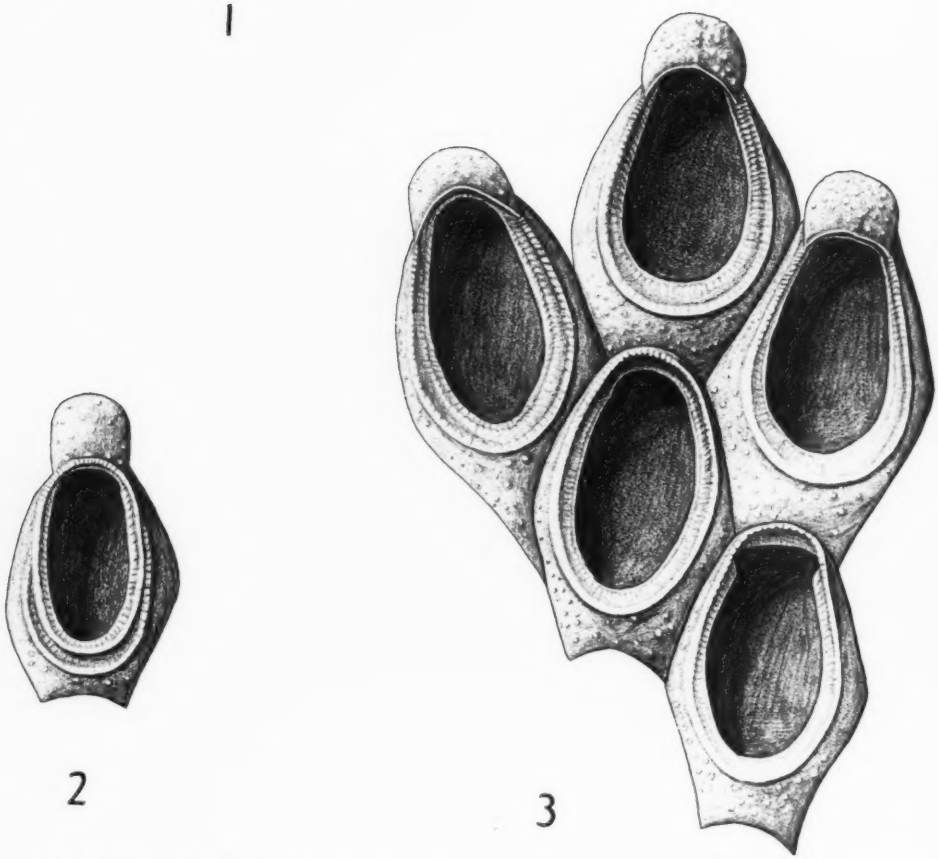

2 3

Cheetham, Early Cretaceous cheilostome bryozoan from Texas

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 177–184, PL. 20, 5 TEXT FIGS., MARCH 1954

A NEW EARLY CRETACEOUS CHEILOSTOME BRYOZOAN FROM TEXAS

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ABSTRACT—Discovery of *Wilbertopora mutabilis* Cheetham, new genus and species, in the Fort Worth limestone in north-central Texas not only extends the known stratigraphic range of Cheilostomata below the Cenomanian, but also appears to substantiate Silén's (1945) belief that possession of ovicells is a primitive characteristic in cheilostome Bryozoa.

INTRODUCTION

WITH the possible exception of the Silurian and Devonian genus *Paleschara* Hall, which Bassler (1935) classified in the order Cheilostomata, cheilostome Bryozoa have not been found heretofore in rocks definitely older than Cenomanian. In Europe, Cheilostomata are represented in Upper Cretaceous deposits by abundant and diversified faunas which have been studied by d'Orbigny (1849–1852), Canu (1900, 1902, 1919), Gregory (1909), Lang (1914a, 1914b, 1915, 1921, 1922), Brydone (1914, 1916–1918, 1929, 1930, 1936, 1942), Barroso (1923), Voigt (1930, 1949), Gillard (1937, 1940, 1942), Allègre (1936), Berthelsen (1948), and others. American Cretaceous rocks, in contrast, have yielded little cheilostome material. Canu (1911) described some Danian cheilostomes from Argentina, and Canu and Bassler (1926) studied a faunule from the Ripley formation (Maestrichtian) in Tennessee. The greatly diversified New Jersey Vincentown fauna, thought by Canu and Bassler (1933) to be Danian, is now considered Eocene by many geologists (e.g., Greacen, 1940).

Therefore, discovery of cheilostomes in the Texas Lower Cretaceous is interesting not only because of their seeming scarcity in North American Cretaceous rocks, but also because of phylogenetic implications.

All specimens in the new faunule appear to be conspecific, and are here described as *Wilbertopora mutabilis* Cheetham, new genus and species, and assigned to the family Calloporidae Norman. Although calloporids are unspecialized in other respects, Canu and Bassler (1927, as Alderinidae) and Bassler (1953) considered them relatively advanced systematically because they possess ovicells, calcified chambers in which fertilized eggs develop into larvae in reproduction of colonies. However, Silén (1945), through his studies of comparative anatomy and embryology of living cheilostomes, has come to believe that Calloporidae are close to the root stock of Cheilostomata. According to his views, ooeciferous (ovicell-bearing) cheilostomes are the unspecialized ones. They produce larvae which lack functional digestive tracts, and which must find a place to become attached and to metamorphose in a few hours. In non-ooeciferous cheilostomes, larvae are of the cyphonautes type; these larvae have working alimentary systems and are able to remain planktonic for several weeks. Cyphonautes larvae, in contrast to the other type, can be produced in great numbers by a single mother zooid because they are ejected at the beginning of their embryological development, i.e., almost immediately after fertilization of the ovum. Therefore, non-ooeciferous Cheilostomata

EXPLANATION OF PLATE 20

FIGS. *1–3*—*Wilbertopora mutabilis* Cheetham, new genus and species. *1*, ancestroecium and blastozooecia of first five generations, ×20; *2*, ooeciferous zooecium regenerated from fifth-generation autozooecium, ×80; *3*, fifth-generation autozooecia and sixth-generation ooeciferous zooecia, ×80. Holotype no. 4600. (p. 180)

are better equipped for competition in environments in which the substratum offers only widely scattered places suitable for attachment and metamorphosis of larvae. Silén's hypothesis that this condition is a secondary adaptation, rather than a primitive characteristic, apparently is substantiated by discovery of ovicells in *Wilbertopora*, the oldest undoubted cheilostome known.

SUMMARY OF STRATIGRAPHY

Wilbertopora mutabilis was found in samples of Fort Worth limestone (Washita group, Comanche Series) collected by Messrs. Jesse W. West and W. F. Roux during the spring of 1952 at a highway bridge over a tributary of Hickory Creek, $1\frac{1}{4}$ miles northwest of Krum, Texas (fig. 1). The stratigraphic position of the Fort Worth limestone is shown in figure 2.

According to Adkins (1932), the Fort Worth consists of cream-colored limestones and dark-gray clay-marls in an alternating sequence of thin beds. The thickness of the formation is relatively constant, varying between 25 and 35 feet, throughout its areal extent. Marls predominate in the lower third of the formation, whereas limestones comprise the major portion of the upper two-thirds.

Fort Worth ostracodes were described by Alexander (1929); Adkins (1932) listed

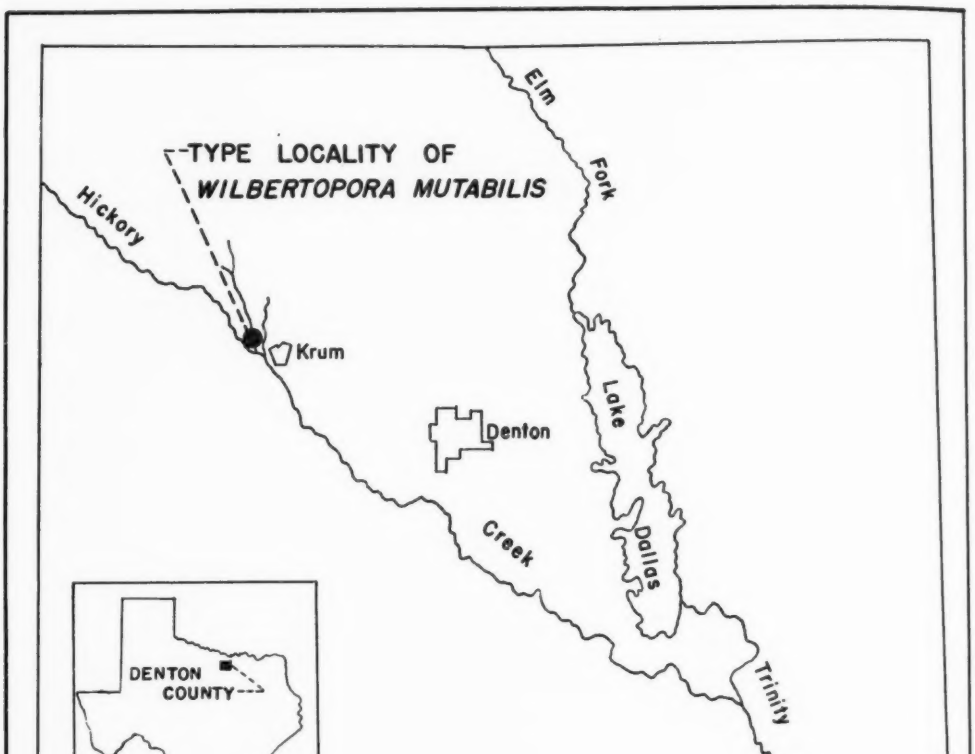

FIG. 1—Schematic map of Denton County, Texas, showing locality from which *Wilbertopora mutabilis* Cheetham, new genus and species, was collected.

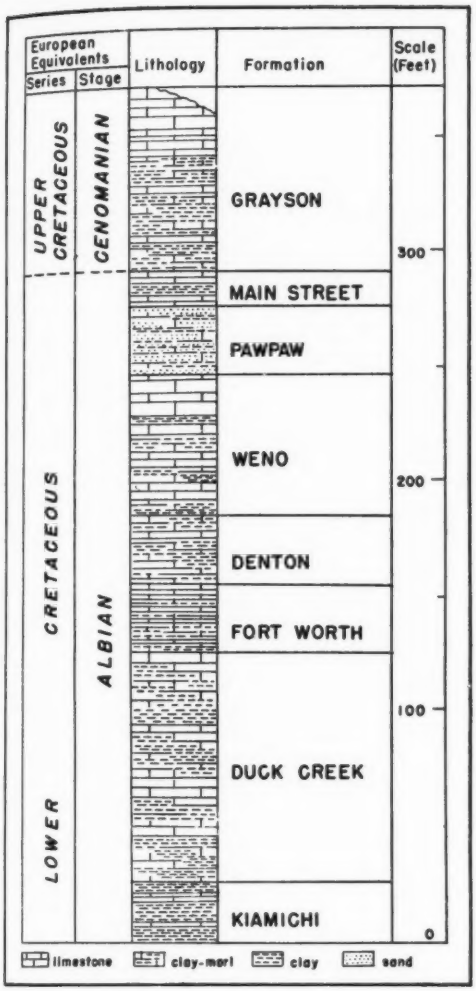

FIG. 2—Generalized lithologic character and stratigraphic correlation of the Washita group in north-central Texas.

many foraminifers, pelecypods, cephalopods, and echinoids which occur in the formation.

More than half the organic calcium-carbonate material in the Fort Worth limestone consists of fragmented remains of the echinoids *Holaster simplex* Shumard and several species of *Macraster*. *Wilbertopora mutabilis* constitutes less than five percent of the fossil content and occurs as incrustations chiefly on fragments of echinoid tests, but also on worm tubes and fragments of *Exogyra* shells. Zoaria of *W. mutabilis* were found on both interior and exterior surfaces of echinoid tests, a single zoarium sometimes continuing from interior to exterior. This relationship suggests that the substratum upon which *W. mutabilis* lived consisted of at least partly fragmented shell material, and that the substratum was at times subjected to the disturbing influence of more deeply penetrating waves.

ACKNOWLEDGMENTS

This paper is the result of part of the research carried out at Louisiana State University during the tenure of a Humble Oil and Refining Company fellowship. Dr. H. V. Howe, director of the School of Geology, and Dr. G. E. Murray, professor of geology, L. S. U., have been instrumental in shaping many aspects of this study. I am indebted to Mr. Jesse W. West, former curator of geology museums, L. S. U., for access to the samples studied for this paper. Many of the observations and conclusions presented herein were discussed with Dr. Louis J. Wilbert, Jr., before his untimely death, and to him must go credit for his untiring efforts in guiding and inspiring my work.

TYPES

All type material discussed and figured in this paper is deposited in the H. V. Howe Collection, Louisiana State University Geology Museum, Baton Rouge.

SYSTEMATICS

Order CHEILOSTOMATA Busk, 1852
Suborder ANASCA Levinsen, 1909
Superfamily MEMBRANIPORACEA Vigneaux, 1949
Family CALLOPORIDAE Norman, 1903
Genus WILBERTOPORA Cheetham, new genus

Diagnosis.—Frontal wall of zooid uncalcified, but bounded proximally and proximolaterally by a calcified gymnocyst. Ancestroecium (skeleton of ancestrula, first zooid of colony formed by metamorphosis of larva) shaped like, but smaller than, blastozooecia (skeletons of zooids formed by budding from ancestrula and successive zooids). Ooeciferous zooecia, only heterozooecia present, differ from autozooecia (normal zooecia of Canu and Bassler) only in possessing a small ovicell placed above

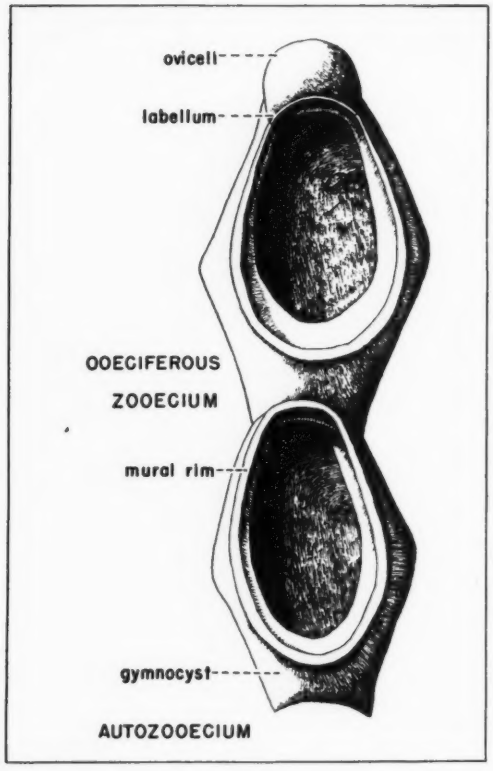

FIG. 3—Skeletal terminology in *Wilbertopora* Cheetham, new genus.

and beyond distal part of mural rim and partly immersed in gymnocyst of distally adjacent zooecium (therefore, a hyperstomial ovicell). Communication between adjacent zooecia through pores placed distally and distolaterally in vertical walls of zooecium without intervening chamberlets (dietellae).

Type species.—*Wilbertopora mutabilis* Cheetham, new species. Fort Worth limestone, Denton County, Texas.

Derivation of name.—This genus is dedicated to Louis J. Wilbert, Jr.

Affinities.—The structure of *Wilbertopora* is simpler in all respects than that of any other known calloporid genus. The absence of dietellae and of heterozooecia other than ooeciferous zooecia reserves for it the position of most primitive known member of the family. From *Alderina* Norman, *Wilbertopora* differs in having interzooecial communication directly by pores rather than with intervening chamberlets, and probably should be regarded as the direct ancestor of that genus.

WILBERTOPORA MUTABILIS Cheetham, new species
Plate 20, figures 1–3

Diagnosis.—Zoarium membraniporiform (unilaminar, incrusting, directly adherent to substratum). Zooecia basically arranged in bilaterally symmetrical pattern around ancestroecium; but symmetry commonly lost during astogeny through different rates of budding on opposite sides of ancestroecium. Ancestrula and each blastozooid of first generation gave rise to three blastozooids; one, two, or three zooids arose from each blastozooid of second and succeeding generations. Blastozooecia of each of first five generations successively larger than those of preceding one; blastozooecia of fifth and succeeding generations retain subequal dimensions.

Zooecia subhexagonal, having a somewhat elongate caudal portion covered by a finely granular, gently convex gymnocyst which is continuous with lateral walls. Mural rim finely crenulate, salient; inner margin oval, concave proximally and proximolaterally forming an incipient cryptocyst.

Distal and lateral walls very low, making zooecial interior shallow. Distal wall and distolateral walls each have a single pore about midway between basal and frontal margins.

Basal wall not calcified; basal edges of distal and lateral walls adhere directly to substratum.

Ooeciferous zooecia occur in fifth and succeeding blastozooidal generations. Ovicell hyperstomial (except for one entozooecial ovicell in holotypic zoarium), finely granular, globular, salient, not deeply imbedded in distally adjacent zooecium. Labellum of ovicell highly arched, making orifice large and nearly perpendicular to frontal surface of zooecium.

Type specimens.—Holotype no. 4600, a mature zoarium; paratype no. 4601, a mature zoarium; paratype no. 4602, an immature zoarium.

Derivation of name.—The name *mutabilis* (mutable, capable of being mutated) was selected to call attention to the mutational

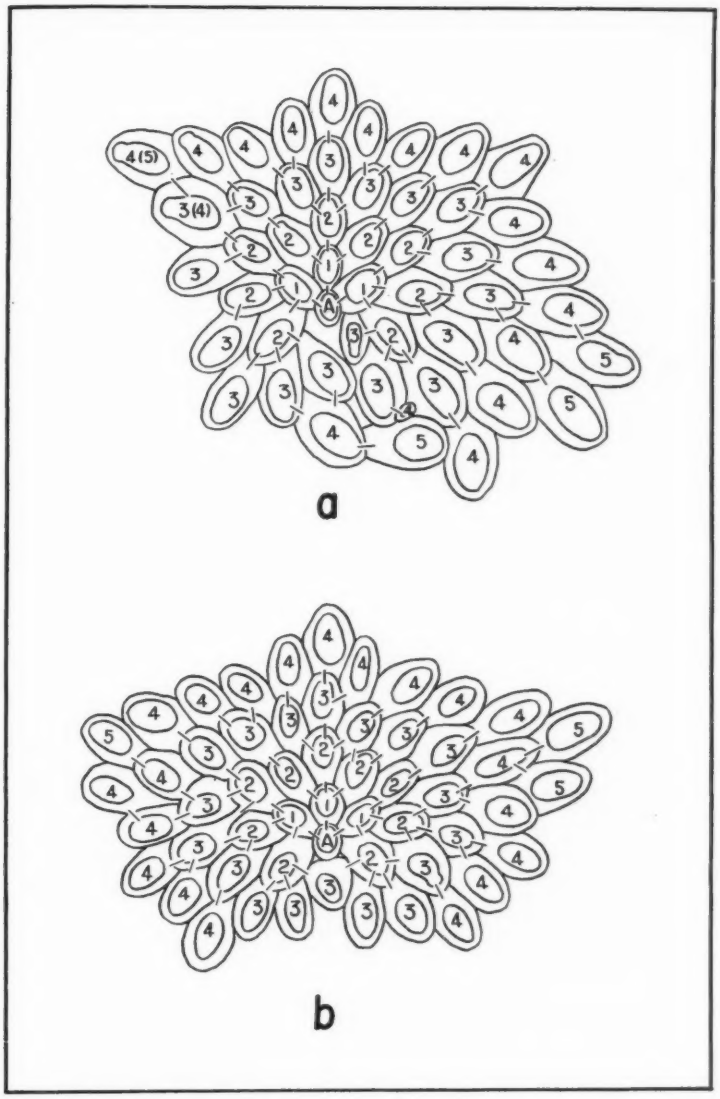

FIG. 4—Astogeny in *Wilbertopora mutabilis* Cheetham, new genus and species. *a*, markedly asymmetrical budding in holotype no. 4600; *b*, nearly symmetrical budding in paratype no. 4602. ×20. (Ancestroecium designated "A"; numbers refer to blastozooidal generations.)

variability in ovicell morphology in this species.

Distribution.—*W. mutabilis* occurs in the Fort Worth limestone, Washita group, Comanche Series, 1¼ miles northwest of Krum, Denton County, Texas. The holotype and paratype no. 4601 are from the upper (limestone) beds; paratype no. 4602 is from a marl bed near the base.

Variations.—Only three specimens in which the ancestrular region is preserved were found. Of these, one (paratype no. 4602) displays the completely symmetrical pattern proximal to the ancestroecium noted by Waters (1924) in *Electra pilosa* (Linné), whereas in the other two specimens the portion of the zoarium immediately proximal to the ancestroecium lost its symmetry by

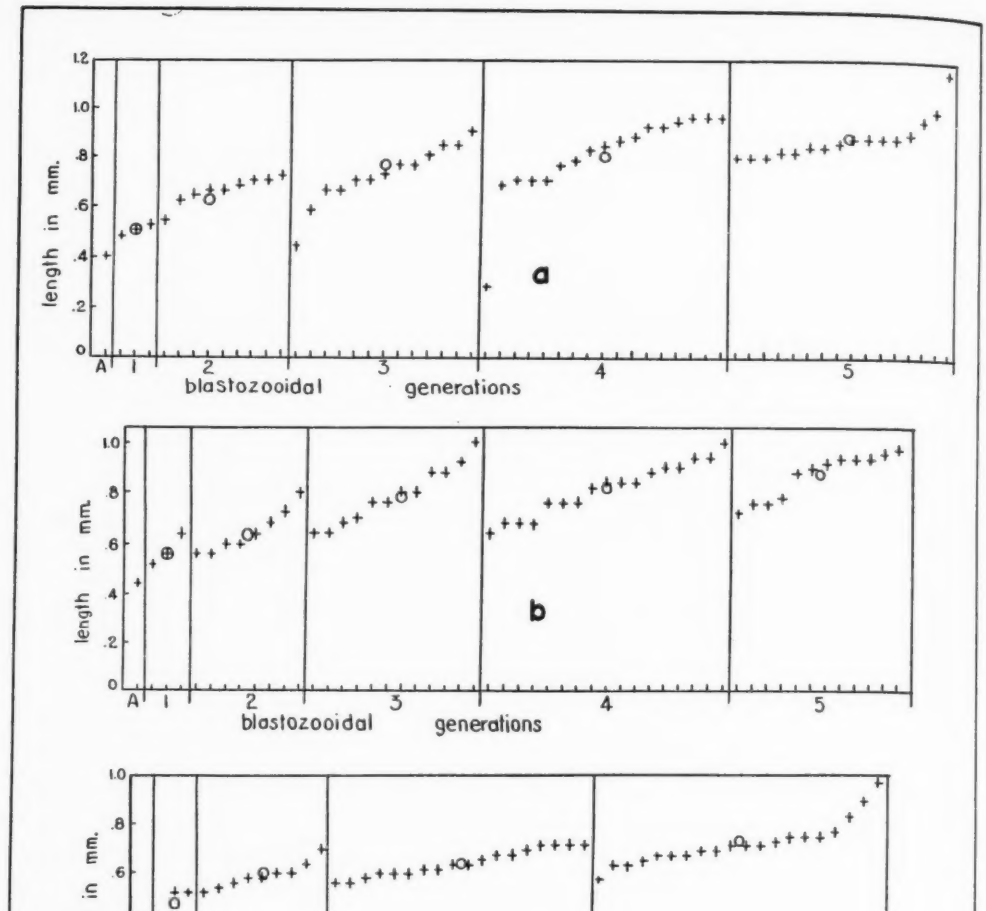

FIG. 5—Variation in length of zooecium in ancestroecium and first five blastozooidal generations of *Wilbertopora mutabilis* Cheetham, new genus and species. Each division of horizontal scale represents one zooecium; mean values for each generation are indicated by circles. *a*, holotype no. 4600; *b*, paratype no. 4601; *c*, paratype no. 4602.

more rapid budding of blastozooids on the left side. This differential rate of development resulted in production of several "dwarfed" or vestigial zooids in the third and fourth generations on the right side of the ancestrula (fig. 4a). Ideally, as demonstrated by Waters in *E. pilosa*, and as exhibited by paratype no. 4602 of *W. mutabilis*, bilateral symmetry is preserved through production of a single zooid proximal to the ancestrula by the two most proximal second-generation blastozooids (fig. 4b). Waters noted that such a zooid, produced by a pair of asexual parents, is larger than the normally budded zooids of its generation, and that it frequently has two polypids.

An asexual union of this type seemingly took place in another part of the zoarium of the holotype of *W. mutabilis*, for a zooecium with adult dimensions occurs in the third (or fourth) generation.

Another variation, observed only in the holotypic zoarium, is a case of regeneration, i.e., an ooeciferous zooecium budded within the walls of an autozooecium. But, in contrast to all other ooeciferous zooecia in the holotypic zoarium, the regenerated zooecium bears an entozooecial ovicell, an ovicell developed from a globular expansion of the distal wall of the zooecium so that its labellum coincides with the distal part of the mural rim (pl. 20, fig. 2).

This colonial mosaicism apparently can be attributed to a developmentally late mutation in the genotypic character of the zoarium. A phenomenon which parallels the mosaicism in *W. mutabilis* has been documented by McLaren and Sutherland (1949) in *Lithostrotion* and related genera. Among these colonial rugose corals, one or several corallites having characters usually regarded as belonging to a different, but related, genus occur in the same corallum with corallites having "normal" characters.

If the classification of Canu and Bassler (1927) or that of Bassler (1953) be followed, the mutation or mutations responsible for occurrence of an entozooecial ovicell in the same zoarium as hyperstomial ones must be placed in a "macromutation" category, for a difference of this magnitude is deemed by Canu and Bassler to be sufficient to separate families. However, Silén (1945) feels that there is little or no fundamental difference between entozooecial and hyperstomial ovicells.

Seemingly large effects have been observed to be produced by micromutations in organisms in which smaller details of reproductive processes are phylogenetically recent acquisitions. For instance, Gordon (1937) found various inversions in the sexual mechanism of the fish *Platypoecilus* which has attained bisexuality late in its phylogenetic history.

Because the capacity to produce ovicells, rather than any one particular type of ovicell, was inherited by *Wilbertopora* from its procheilostome ancestor, it does not seem too speculative to imagine that myriad micromutations, some doubtless with effects too small to be observed in fossil specimens, molded a genic complex capable of controlling production of many morphologically different types of ovicells, which, through their relative efficiencies in various environments, tended to become more stable genetically and less plastic morphologically.

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CHECK LIST OF INDIAN TERTIARY LARGER FORAMINIFERA

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ABSTRACT—This check list summarizes all pertinent contributions to the knowledge of Indian Tertiary larger Foraminifera. It includes all larger foraminiferal species so far described from the Indian region.

INTRODUCTION

EARLY in December, 1947, I sent Brooks F. Ellis, of the Department of Micropaleontology, American Museum of Natural History, a check list of Indian Tertiary and post-Tertiary Formainifera to assist him in work he had in progress and to provide a check on the material included in the "Catalogue of Foraminifera." Since then, as notes were periodically added, the list has grown to its present size. Some colleagues suggested that it would be useful for workers on Indian Foraminifera if such a list could be widely circulated. This article is the result. I hope that the list will help to clear existing confusion in nomenclature and stimulate discussion of the rather complex problems associated with larger Foraminifera in India and adjacent areas.

The check list is prepared in the same form as the "Check list of Tertiary larger Foraminifera of Japan" by Hanzawa (1947). It is a complete index including bibliographic references to all the Tertiary larger Foraminifera from the Indian region that so far have been described as new or have been adequately figured and described.

The list of paleontologists who have worked with Indian larger Foraminifera includes J. de C. Sowerby, E. J. A. d'Archiac, J. Haime, H. J. Carter, H. Douvillé, E. Vredenburg, W. L. F. Nuttall, L. M. Davies, M. de Cizancourt and S. R. N. Rao. Sowerby (1837) described a collection of fossils from Cutch, some of which were later redescribed by Nuttall (1926). D'Archiac and Haime (1853) in their classical monograph on the genus *Nummulites*, recorded 18 species of *Nummulites* and *Assilina* but failed to state the exact localities from which their figured specimens were collected. Because d'Archiac and Haime's species were described from widely different parts of the country at a time when little was known of the geological succession of the tertiaries, no effort was then made to separate the species stratigraphically. Thevenin (1903) examined some specimens from the d'Archiac collection but found some of the forms to be inadequately labelled or even lost. Nuttall (1926) in his studies of Foraminifera of parts of western India redescribed some of these forms. Carter (1853, 1861) described some Foraminifera from Sind and Cutch which were later revised by Nuttall (1926). Vredenburg (1906) described a new species of *Nummulites* (*N. douvillei*) from Cutch which is a synonym of *N. acutus* Sowerby.

More recently, Nuttall (1925, 1926) described larger Foraminifera from the Laki and Khirthar series of western India. Davies (1939, 1940) studied Foraminifera from the northwestern part of the Indian region. Rao (1943) restudied Douvillé's (1916) collection from the Kam-pa System of Tibet and also described Foraminifera from the upper Eocene of Surat and Broach area (1941). De Cizancourt (1938) described some larger Foraminifera from the Indo-Afghan border.

CHECK LIST

Each entry is arranged alphabetically and carries the generic and specific name, author, date, reference, formation and age, and exact locality. The depository of the forms, whenever known, also is given. The author's remarks are given in parentheses at the end of each entry.

Abbreviations here used for depositories are:

G.S.I.—Geological Survey of India.
British Museum (N.H.)—British Museum (Natural History).

Actinocyclina alticostata, n. sp., Nuttall, 1926b, p. 151, pl. 8, figs. 6, 7, 8. Middle Khirthar. Two miles W. of Lakhimirani and 1¼ miles E. of Shadwan, W. Cutch.

Actinocyclina cf. *A. crassicostata* Douvillé. Tewari, 1949, p. 401, 1 fig. Upper Khirthar. Surat and Broach area.

Assilina cancellata, n. sp., Nuttall, 1926b, pp. 141–142, pl. 5, figs. 1–3. Middle Khirthar. Rohri; Kot Frji; Jhand Mahomed; Sukkur, Sind.

Assilina dandotica, n. sp., Davies, 1937, pp. 28–29, pl. 4, figs. 1–3, 6–8. Upper Ranikot, Kalabagh to Dandot. Holotype G.S.I. Type No. 15811.

Assilina daviesi, n. sp., de Cizancourt, 1938, p. 23, pl. 3, figs. 18, 25, 26. Laki. Near Gardez, Afghanistan.

Assilina exponens (Sowerby). Nuttall, 1926b, pp. 142–143, pl. 5, figs. 5–6; pl. 6, fig. 1. Middle Khirthar. One mile S. of Waghapadar (Waggerpudder); Mardan Nala, Mula River, Kelat State; N.E. and W. of Pabuni Chauki, Las Bela State; Pab Range, W. of Shah Bilawal (Bilal), Las Bela State; Taghoa, Loralai dist. Baluchistan; Sham Plain, Bugti Hills.

Assilina granulosa (d'Archiac). Nuttall, 1925a, pp. 441–443, pl. 26, figs. 1, 5. Laki. Meting; Mukli Hills near Tatta; Laki limestone, W. of Bund Vera Plain; Ghazij shales, Shero Kund Nala (W. of Bibi Nani); Ghazij shales (W. of Gokurth, Bolan Pass); Fort Munro; Ghazij shales, Sham Plains (Bugti Hills).

Assilina granulosa (d'Archiac). De Cizancourt, 1938, p. 25, pl. 3, fig. 28. Laki. Near Gardez, Indo-Afghan border.

Assilina irregularis, n. sp., Carter, 1853, p. 168, pl. 7, figs. 5–6. Khirthar. Schinde (Sind).

Assilina irregularis Carter. Carter, 1857, p. 580, pl. 23, figs. 5–6. Middle Khirthar. Valley of Kelat.

Assilina irregularis Carter. Davies, 1940, p. 215, pl. 11, fig. 9. Middle Khirthar. Sind; Baluchistan and Kohat.

Assilina mamillata (d'Archiac). Nuttall, 1926b, p. 143, pl. 6, fig. 4. Laki. (Megalospheric form of *A. exponens*.)

Assilina mamillata (d'Archiac). De Cizancourt, 1938, p. 25, pl. 3, fig. 17. Lower Khirthar. Near Gardez, Indo-Afghan border.

Assilina obesa, n. sp., Carter, 1861, p. 368, pl. 15, figs. 2a–2d. Khirthar. Valley of Kelat. (=*A. mamillata*)

Assilina papillata, n. sp., Nuttall, 1926b, pp. 144–145, pl. 6, figs. 5–7. Middle Khirthar. Sukkur, Sind; Kubba Shadi Shahid, 4 miles SE of Khairpur, Sind; range SE of Damach, Thana Bula Khan taluqa, Karachi dist.; W. of Laki village. (=*A. irregularis* Carter)

Assilina papillata Nuttall. Davies, 1940, pp. 214–215, pl. 11, figs. 1, 3, 6, 8, 10–12. Middle Khirthar. Kohat-Potwar Basin; Waziristan; Sirki Paila (Sirki Pela). (=*A. irregularis* Carter)

Assilina cf. *A. pustulata* Doncieux. Davies, 1937, pp. 34–35, pl. 4, figs. 13–15, 18, 22. Laki. Near Sehti; Nurpur; Kallar Kahar; Dalwal (5½ miles WSW of Choa Saidan Shah); Kohat.

Assilina ranikoti, n. sp., Nuttall, 1926a, p. 117, pl. 10, figs. 7–11. Upper Rainkot. One mile SE of Petiana (G.S.I. No. G. 280/135); Jherruck (G.S.I. No. 280/124a); 38 miles NW of Kotri; 4½ miles SE of Meting; 5 miles SE of Hilaia.

Assilina ranikoti Nuttall. Davies, 1927, p. 274, pl. 21, fig. 16. Upper Ranikot. Thal.

Assilina rota, n. sp., Davies, 1940, pp. 215–216, pl. 11, figs. 2, 4–5, 7, 13. Upper Khirthar (lower level). Spintangi and Kohat. Holotype, British Museum (N.H.) No. P. 35038.

Assilina spinosa, n. sp., Davies, 1937, pp. 31–34, pl. 4, figs. 11–12, 16–17. Upper Ranikot to Laki. Kalabagh to Chamil (Ranikot); Chamil to Dandot (Laki); Thal (Ranikot). Holotype G.S.I. Type No. 15821.

Assilina spira (de Roissy). Nuttall, 1926b, pp. 143–144, pl. 6, figs. 8–9. Middle Khirthar. Rohri (Sind).

Assilina subcancellata, n. sp., Nuttall, 1926b, p. 142, pl. 5, fig. 4. Middle Khirthar. Rohri (Sind).

Assilina subpapillata, n. sp., Nuttall, 1926b, p. 145, pl. 6, figs. 2–3. Middle Khirthar. Sukkur, Sind; Kubba Shadi Shahid (4 miles SE of Khairpur); Kort Deji, Sind; range SE of Damach, Thana Bula taluqa, Karachi dist.; W. of village Laki. (Megalospheric form of *A. papillata* Nuttall.)

Assilina subspinosa, n. sp., Davies, 1937, pp. 33–34, pl. 4, figs. 19–20, 23–26. Upper Ranikot to Laki. Kalabagh to Chamil (Ranikot); Chamil to Dandot (Laki); Thal (Ranikot). Holotype G.S.I. Type No. 15825.

Assilina subumbilicata, n. sp., de Cizancourt, 1938, p. 24, pl. 3, figs. 21–23. Laki. Near Gardez, Indo-Afghan border. (=*A. sublacunata* n. name, de Cizancourt.)

Assilina umbilicata, n. sp., de Cizancourt, 1938, pp. 23–24, pl. 3, figs. 19, 20, 27. Laki. Near Gardez, Indo-Afghan border. (=*A. lacunata* n. name, de Cizancourt; microspheric form of *A. sublacunata*.)

Alveolina elliptica, n. sp., Sowerby, 1837–40, p. 329, pl. 24, figs. 17, 17a. Middle Khirthar. Waggerpudder (Wage-ke-Pudda), Cutch.

Alveolina elliptica Sowerby. Douvillé. 1906, pp. 61–62, pl. 1, fig. 1. Middle Khirthar. Cutch.

Alveolina elliptica Sowerby. Nuttall, 1925b, pp. 378–382, pl. 20, figs. 1–5. Middle Khirthar. Waggerpudder, Cutch; Baboa Hills, Cutch; Lukput, Cutch (British Museum No. 561); Boobon's Cave, Sylhet (British Museum No. 54976); Illiasi Nala, 10 miles west of Kumbhi, Bugti Hills; Sukkur, Sind.

Alveolina elliptica Sowerby. Davies, 1940, pp. 218–219, pl. 12, figs. 5, 7. Middle to upper Khirthar. Spintangi; Kohat; Kelat; Bugti Hills; Sukkur; Siju.

Alveolina elliptica Sowerby var. a Nuttall, 1925b, p. 382, pl. 20, figs. 4, 5. Middle Khirthar. Waggerpudder and Gothahad (Cutch).

Alveolina elliptica Sowerby var. b Nuttall, 1925b, pp. 383–384, pl. 20, fig. 2. Middle Khirthar. Cutch, Sind, Baluchistan.

Alveolina elliptica Sowerby var. *nuttalli*, n. var., Davies, 1940, pp. 219–220, pl. 12, figs. 1–4.

Middle and upper Khirthar. Kohat; Cutch. Holotype, British Museum (N.H.) No. P. 35044.

Alveolina lepidula Schwager. Nuttall, 1925a, pp. 139–140, pl. 24, figs. 1–2. Laki. Parri Nala, Bolan Pass.

Alveolina meandrina, n. sp., Carter, 1861, pp. 381–382, pl. 17, fig. 42-f. Ranikot. Valley of Kelat. (This is a *Miscellanea*.)

Alveolina melo d'Orbigny. Carter, 1853, p. 170, pl. 7, fig. 15. Schinde. (? = *A. globosa*)

Alveolina oblonga d'Orbigny. Douvillé, 1916, pp. 42–43, pl. 16, figs. 3–5. Laki. Kam-Pa Dzong, Tibet.

Alveolina oblonga d'Orbigny. Nuttall, 1925a, pp. 446–447, pl. 27, fig. 8, text fig. 5. Upper Ranikot, Laki. Meting; Mukli Hills; Tatta; Laki limestone west of Ranikot (G.S.I. No. K 61926 and K 7/869); Laki limestone, 5 miles south of Bund Vera. (G.S.I. No. 280/86); upper Ranikot, Jherruck.

Alveolina oblonga d'Orbigny. Nuttall, 1926a, p. 110. Upper Ranikot. Jherruck (G.S.I. No. G. 280/124a); northeast of Petiani (G.S.I. No. G. 280/135); 5½ miles southeast of Meting.

Alveolina oblonga d'Orbigny. Davies, 1940, p. 221, pl. 7, fig. 6, Laki. Spintangi.

Alveolina ovicula, n. sp., Nuttall, 1925a, p. 439, pl. 24, figs. 9, 10. Laki. Ghazij shales, Parri Nala (Bolan Pass).

Alveolina subpyrenaica Leymerie. Nuttall, 1925a, pp. 434–435, pl. 23, figs. 1–3; pl. 24, fig. 3. Laki. Meting; Mukli Hills near Tatta; Laki limestone on the west side of Bund Vera Plain near Murid; Laki limestone, 5 miles southeast of Bund Vera (G.S.I. No. G. 280/86); Hyderabad, Sind, British Museum (N.H.) No. P. 570; Para Nala, west of Bibi Nani (Bolan Pass), Fort Munro (Dehara Ghazi Khan).

Alveolina spheroidea Lamarck. Carter, 1853, p. 170, pl. 7, fig. 16. Schinde (Sind).

Alveolina vredenburgi, n. sp., Davies, 1937, pp. 57–58, pl. 5, fig. 25. Ranikot. Salt Range, Patala westwards; Kala Chitta Range; Thal.

Conulites cooki, n. gen., n. sp., Carter, 1861, pp. 457–458, pl. 15, fig. 7a–g. Khirthar. Valley of Kelat. (= *Dictyoconoides cooki* [Carter]).

Conulites kohaticus, n. sp., Davies, 1926, pp. 240–246, pls. 16–17, figs. 1–6. Middle Khirthar. Kohat. (= *Dictyoconoides kohaticus*)

Conulites kohaticus Davies, 1932, p. 405, pl. 1, figs. 2, 6, 8, 10, 11, 12a, b, d, 13, 14; pl. 2, fig. 1. Middle Khirthar. Kohat. Lectotype G.S.I. No. 13-44. (= *Dictyoconoides kohaticus*)

Conulites tipperi, n. sp., Davies, 1926, pp. 247–248, pl. 18, fig. 8. Laki. Petiani. (= *Lockhartia tipperi*)

Conulites vredenburgi, n. sp., Davies, 1926, pp. 246–247, pl. 17, figs. 7–7b. Laki. Ghazij shales, Hindu Bagh (Baluchistan).

Coskinolina balsilliei, n. sp., Davies, 1930a, pp. 496–497, pl. 1, figs. 6–9; pl. 2, figs. 4–6, 15. Laki. Ghazij shales, Hindu Bagh (Baluchistan).

Dictyoconoides cooki (Carter). Nuttall, 1925b, pp. 384–386, pl. 21, figs. 1–9. Middle Khirthar. Gothahad (Cutch); 1 mile south of Waggerpudder; Illiasi Nala, Bugti Hills; 5 miles south of Dehra Bugti, Bugti Hills; shales west of Habb River, west of Khand Jhand (Karachi); west of Dawagar, Dehra Khan foot-hills; Drug, Baluchistan; Taghoa, Loralai dist. Baluchistan; Kohat (British Museum (N.H.) No. P. 22384–22408).

Dictyoconoides cooki (Carter). Davies, 1932, p. 405, pl. 1, figs. 9, 12c and e. Middle Khirthar. Sind. Lectotype British Museum (N.H.) No. P. 28572.

Dictyoconoides conditi, n. sp., Nuttall, 1926a, p. 119, pl. 11, figs. 7–8. Upper Ranikot. Jherruck (G.S.I. No. G. 280/124a); NE of Petiani (G.S.I. No. G. 280/135); 5½ miles SE of Meting. (= *Lockhartia conditi*)

Dictyoconoides conditi Nuttall. Davies, 1927, p. 279, pl. 21, figs. 10–12, pl. 22, fig. 5. Upper Ranikot. Thal.

Dictyoconoides conditi Nuttall. Davies, 1930b, p. 76–77, pl. 10, fig. 9. Upper Ranikot. Samana Range.

Dictyoconoides conditi Nuttall var. *roeae*, n. var., Davies, 1930b, pp. 76–77, pl. 10, fig. 9. Upper Ranikot. Samana Range. (= *Lockhartia conditi roeae*)

Dictyoconoides flemingi, n. sp., Davies, 1937, p. 51, pl. 6, figs. 11–13. Upper Ranikot. Salt Range, Dhak Pass to Kallar Kahar. Holotype G.S.I. No. 15883.

Dictyoconoides haimei, n. sp., Davies, 1927, pp. 280–281, pl. 21, figs. 13–15; pl. 22, fig. 6. Upper Ranikot. Thal. (= *Lockhartia haimei*)

Dictyoconoides haimei Davies, 1930b, pp. 75–76, pl. 10, figs. 6–7. Upper Ranikot. Samana Range.

Dictyoconoides newboldi (d'Archiac and Haime). Davies, 1927, pp. 279–280, pl. 22, figs. 1–4. Upper Ranikot, Thal. (= *Rotalia newboldi*)

Dictyoconoides newboldi (d'Archiac and Haime). Davies, 1930b, pp. 74–75, pl. 10, fig. 8. Upper Ranikot, Samana Range.

Dictyoconoides vredenburgi (Davies). Davies, 1932, p. 406; pl. 1, figs. 1, 3, 4, 5, 7; pl. 2, figs. 2–3; pl. 3, fig. 14. Laki. Lectotype, G.S.I. No. 15316.

Dictyoconoides indicus, n. sp., Davies, 1930a, pp. 497–499, pl. 1, figs. 10–13; pl. 2, figs. 7–11, 13, 16. Laki. Ghazij shales, Hindu Bagh, Baluchistan.

Discocyclina archiaci (Schlumberger) var. *baluchistanensis*, n. var., Nuttall, 1925a, pp. 446–447, pl. 27, fig. 1, text fig. 5. Laki. Triangulation station 1485, Garai Nala (west of Gokurth), Bolan Pass.

Discocyclina dispansa (Sowerby). Nuttall, 1926b, pp. 145–147, pl. 7, figs. 1–3, 5. Middle Kirthar, 1 mile south of Waghapadar (Waggerpudder), Cutch; 2 miles southwest of Godhathad (Gothahad), Cutch; 2 miles west of Lakhimirani, Cutch; northeast of Drug, Loralai dist., Baluchistan; Taghoa, Loralai dist., Baluchistan.

Discocyclina javana (Verbeek) var. *indica*, n. var., Nuttall, 1926b, pp. 147–148, pl. 7, figs. 4, 6, 7; pl. 8, fig. 4. Middle Khirthar. One mile south of Waghapadar (Waggerpudder), Cutch; 3 miles west of Sehe; 2 miles west of Lakhimirani,

Cutch; 1½ miles east of Jhadwan, western Cutch; east of Garmaf hot springs, Buzdar tribal tract, Dehra Ghazi Khan dist., Punjab; Taghoa, Loralai dist., Baluchistan; Kalu Kushtak Nala, 5 miles northwest of Dehra Bugti, Bugti Hills, Baluchistan; northeast and west of Pabuni Chauki, Las Bala State; Madran Nala, Mula River, Kelat State.

Discocyclina ranikotensis, n. sp., Davies, 1927, pp. 281–282, pl. 22, figs. 10–12, text fig. 4. Upper Ranikot. Thal.

Discocyclina ranikotensis Davies, 1937, p. 55, pl. 3, fig. 22. Upper Ranikot to Laki. Salt Range, Kala Bagh to Patala; Kallar Kahar; Choa Saidan Shah; Kala Chitta Range, Sind. Holotype G.S.I. No. 13552.

Discocyclina sowerbyi, n. name, Nuttall, 1926b, pp. 149–150, pl. 8, figs. 1–3. Middle Khirthar. One and a half miles north of Waghapaddar; 2 miles southwest of Godhathad; 1½ miles east of Jhadwan; 2 miles west of Lakhimirani, western Cutch; Taghoa, Loralai dist., Baluchistan; east of Drug, Loralai dist., Baluchistan; east of Garmaf, Buzdar tribal tract; Mardan Nala, Mula River, Kelat State; Kot Deji, Sind; west of Laki village, Sind.

Discocyclina undulata, n. sp., Nuttall, 1926b, pp. 150–151, pl. 7, figs. 8, 9; pl. 8, fig. 5. Middle Khirthar. East of Garmaf, Buzdar tribal tract.

Flosculina globosa Leymerie. Nuttall, 1925a, pp. 435–439, pl. 23, figs. 1–4; pl. 24, figs. 4–6. Upper Ranikot to Laki. Meting; Mukti Hills, near Tatta; Parri Nala, Bolan Pass; Fort Munro, Dehra Ghazi Khan; Tochi River (British Museum [N.H.] No. P. 7907); Hilaia triangulation station (upper Ranikot) and 5½ miles southeast of Meting (upper Ranikot).

Heterostegina cf. *H. ruida* Schwager. Davies, 1937, p. 52, pl. 5, fig. 21. Laki. Salt Range; Rutuchha.

Lepidocyclina blanfordi, n. sp., Nuttall, 1926c, pp. 334–336, pl. 8, figs. 5, 6, 9, 10. Gaj. Few miles south of Pirmanjal, north of Karachi.

Lepidocyclina (*Eulepidina*) *dilatata* (Michelotti). Nuttall, 1926c, pp. 331–334, pl. 13, figs. 1–4, text fig. 1. Nari. East of Sari, Thana Bula Khan taluqa; near Khand Jhand, Karachi taluqa; east of limestone ridge, 3 miles northeast of Jungshahi (G.S.I. No. G. 226/57); east of Trak, Kohistan (G.S.I. No. G. 226/58); Gaj River, northwest of Sehwan, Sind (G.S.I. No. G. 226/60); Charlo, south of Sehwan, Sind (G.S.I. No. G. 226/78); east of Trak Hills, north of river, Kohistan (G.S.I. No. G. 280/53); scarp of Kotar Range, west of Damach (G.S.I. No. G. 302/61); Beynir Hills, 10 miles east of Than Shah Beg (G.S.I. No. G. 302/82); between Baili and Khand, Habb Valley (G.S.I. No. G. 304/19); small hill west of Nal, Baluchistan (G.S.I. No. K. 10/319); 10 miles west of Naka (Hindian), west of Mol Plateau, Baluchistan (G.S.I. No. K. 10/429).

Lepidocyclina (*Polylepidina*) *punjabensis*, n. sp., Davies, 1937, pp. 53–55, pl. 7, figs. 1–8, 14, 16, text fig. 3. Upper Ranikot. Salt Range, Kalabagh to Dandot; Kala Chitta Range; Kampa Dzong, Tibet. Holotype G.S.I. No. 15887. (=*Orbitosiphon tibetica*)

Lepidorbitoides polygonalis, n. sp., Douvillé, 1916, p. 35, pl. 15, figs. 1–3. Ranikot. Kampa Dzong, Tibet. (=*Discocyclina polygonalis*)

Lepidorbitoides tibetica, n. sp., Douvillé, 1916, pp. 34–35, pl. 15, figs. 1–6. Upper Ranikot. Kampa Dzong, Tibet. (=*Orbitosiphon tibetica*)

Lituonella douvillei, n. sp., Davies, 1930a, pp. 494–496, pl. 1, figs. 3–5; pl. 2, figs. 1–3, 14. Laki. Ghazij shales, Hindu Bagh.

Lockhartia conditi (Nuttall). Davies, 1932, p. 408, pl. 2, fig. 7; pl. 4, fig. 7.

Lockhartia conditi (Nuttall). Davies, 1937, pp. 47–48, pl. 5, fig. 24. Upper Ranikot. Salt Range, Kalabagh to Dandot; Kala Chitta Range.

Lockhartia haimei (Davies). Davies, 1932, p. 407, pl. 2, figs. 4–6. Holotype G.S.I. No. 13551.

Lockhartia haimei (Davies). Davies, 1937, pp. 45–46, pl. 7, figs. 9–13, 15. Upper Ranikot. Salt Range, Kalabagh to Dandot (with the exception of Chooa Saidan Shah and Rutuchha); Kala Chitta Range; Kampa Dzong.

Lockhartia newboldi (d'Archiac and Haime). Davies, 1937, p. 46, pl. 5, fig. 23. Upper Ranikot. Salt Range, Kalabagh to Dandot; Kala Chitta Range; Kampa Dzong, Tibet. (=*Rotalia newboldi*)

Lockhartia tipperi (Davies). Davies, 1937, pp. 48–49, pl. 6, figs. 14–16; pl. 7, fig. 17. Upper Ranikot to Laki. Salt Range, Kalabagh to Dandot; Kala Chitta Range. Lectotype, G.S.I. No. 13052.

Lycophris dispansus, n. sp., Sowerby, 1837–1840, p. 327, pl. 24, figs. 16, 16a, 16b. Khirthar. Baboa Hill and Waghapuddar (Waggerpudder), Cutch. (=*Discocyclina dispansa*)

Lycophris dispansus Sowerby. Carter, 1853, pp. 172–173, pl. 7, figs. 23–29. Khirthar. Schinde (Sind). (=*Discocyclina dispansa*)

Lycophris ephippium, n. sp., Sowerby, 1837–1840, p. 327, pl. 24, figs. 15a–b. Khirthar. Cutch. (=*Discocyclina sowerbyi* Nuttall)

Miscellanea miscella (d'Archiac and Haime). Davies, 1937, pp. 43–45, pl. 6, figs. 1–3, 5, 7–8. Upper Ranikot. Salt Range, Kalabagh; Kala Chitta Range. (Melagospheric form of *M. stampi*.)

Miscellanea stampi (Davies). Davies, 1937, pp. 42–43, pl. 6, figs. 4, 6, 9, 10, 17, 18, text fig. 1A. Upper Ranikot. Salt Range, Kalabagh to Dandot; Kalabagh to Kallar Kahar; Kala Chitta Range; Kampa Dzong, Tibet. Holotype G.S.I. No. 13550.

Nummulites acutus? Sowerby. Carter, 1853, p. 171, pl. 8, figs. 21–22. Khirthar. Sind. (=*N. intermedius* d'Archiac)

Nummulites acutus Sowerby. Nuttall, 1926b, pp. 133–134, pl. 2, figs. 1–4. Middle Khirthar. Two miles southwest of Gothathad (Gothahad), Cutch; 1 mile south and 1½ mile north of Waghapadar (Waggerpudder), Cutch; east of Drug, Baluchistan.

Nummulites atacicus Leymerie. Nuttall, 1925a, pp. 444–445, pl. 25, figs. 1–6. Laki. Meting; 7 miles SW of Tatta; 5 miles SE of Bund Vera

(G.S.I. 280/86); NE of triangulation 1485 (Garai Nala, west of Gokurth, Bolan Pass); Shero Kund Nala (west of Bibi Nani); Parri Nala (west of Bibi Nani).

Nummulites atacicus Leymerie. Nuttall, 1926b, pp. 129–130. Middle Khirthar. Garmaf hot springs, Bazdar tribal tract, Dehra Ghazi Khan foot hills; NE of Pabuni Chauki, Las Bela State; west of Hab River, west of Khand Jhand, Karachi district; 6 miles northeast of Rarisham, Loralai district, Baluchistan.

Nummulites atacicus Leymerie. Davis, 1937, pp. 24–25, pl. 3, figs. 4, 8, 10. Laki. Salt Range; Kohat.

Nummulites beaumonti, n. sp., d'Archiac and Haime, 1853, pp. 133–134, pl. 8, figs. 1–3. Cherra Poonji (Cherra Punji); Subathoo (Subathu).

Nummulites beaumonti d'Archiac and Haime. Davies, 1940, pp. 206–209, pl. 9, figs. 1–9. Khirthar. Spintangi; Siju.

Nummulites biarritzensis, d'Archiac. D'Archiac and Haime, 1853, p. 131, pl. 8, fig. 4. Pendjab (Punjab) (in part = *N. atacicus*).

Nummulites biarritzensis d'Archiac and Haime. Carter, 1861, pp. 373–374. (= *N. atacicus*).

Nummulites broachensis, n. sp., Carter, 1861, p. 373, pl. 15, fig. 3, Khirthar. Wasna, 15 miles SE of Broach.

Nummulites carteri, n. sp., d'Archiac and Haime, 1853, pp. 343, 344. Khirthar. Sind; Baluchistan.

Nummulites carteri d'Archiac and Haime. Nuttall, 1926b, p. 139, pl. 3, figs. 4–5; pl. 4, fig. 1. Khirthar. Sukkur, Sind.

Nummulites douvillei, n. sp., Vredenburg, 1906, pp. 79–84, pl. 8, figs. 1–13. Khirthar. Lakhpat and Noondatur, Cutch. (= *N. atacicus*).

Nummulites discorbinus d'Archiac and Haime, 1853, pp. 140–141, pl. 9. figs. 2, 3; (no localities given).

Nummulites gizenhensis (Forsk). Nuttall, 1926b, pp. 139–140, pl. 3, figs. 3, 6, 7. Khirthar. Sukkur, Sind.

Nummulites garansensis Joly and Leymerie. D'Archiac and Haime, 1853, pp. 101–102, pl. 3, figs. 6, 7. Nari. Baluchistan; Sind. (= *N. fichteli*)

Nummulites globosus Leymerie var. *indicus*, n. var., Davies, 1927, pp. 271–273, pl. 20, figs. 6–10. Ranikot. Thal.

Nummulites globosus Leymerie. Davies, 1937, p. 22, pl. 3, fig. 3. Ranikot. Nammal; Kalabagh to Chamil; Kala Chitta Range.

Nummulites guettardi, n. sp., d'Archiac and Haime, 1853, p. 130, pl. 7, figs. 18–19. Ranikot. Sind; Baluchistan; Cutch; Punjab.

Nummulites aff. *N. guettardi* d'Archiac and Haime. Nuttall, 1926a, pp. 115–116, pl. 10, figs. 3–4; text fig. 2. Ranikot. Jherruck (G.S.I. No. G. 280/124a); SE of Hilaia trigonometrical station; 5½ miles SE of Meting.

Nummulites irregularis Deshayes. Nuttall, 1925a, p. 446, pl. 26, figs. 6, 7. Laki. Near triangulation 1485 (west of Gokurth, Bolan Pass); Parri Nala (west of Bibi Nani).

Nummulites irregularis Deshayes. Davis, 1937, pp. 26–27, pl. 3, figs. 5, 16, 17, 19. Laki. Jaba to Kalabagh; Choa Saidan Shah.

Nummulites irregularis Deshayes. De Cizancourt, 1938, p. 14, pl. 1, figs. 1, 2, 12. Laki. Gardez.

Nummulites kelatensis, n. sp., Carter, 1861, p. 376, pl. 15, fig. 6. Laki. Valley of Kelat.

Nummulites kelatensis Carter. Davies, 1940, pp. 210–211, pl. 10, figs. 7, 10, 11. Laki. Spintangi (lectotype, British Museum [N.H.] No. P. 33726).

Nummulites laevigatus (Bruguiere's sp.) Nuttall, 1925b, pp. 134–135, pl. 1, figs. 6, 7. Khirthar. West of Pabuni Chauki, Las Bela State; Sukkur, Sind. (This is a new species.)

Nummulites lahirii, n. sp., Davies, 1937, pp. 25–26, pl. 3, figs. 12–15. Ranikot to Laki. Patala Nullah; Kalabagh. (Holotype G.S.I. No. 15799.)

Nummulites leymeriei, n. sp., d'Archiac and Haime, 1853, p. 153, pl. 11, figs. 9–12. Laki. Hala Range and Kalabag (Punjab).

Nummulites lucasana Defrance. D'Archiac and Haime, 1853, pp. 124–127, pl. 7, fig. 10. Khirthar. Subathoo; Silhet. (= *N. perforatus*)

Nummulites lyelli, n. sp., d'Archiac and Haime, 1853, pp. 95–96, pl. 2, fig. 9; pl. 3, figs. 1, 2. Khirthar. Sind; Baluchistan; Cutch. (= *N. gizenhensis*)

Nummulites millecaput Boubee. Davies, 1940, pp. 211–212, pl. 10, fig. 9, Khirthar. Harnai.

Nummulites maculatus, n. sp., Nuttall, 1926a, pp. 140–141, pl. 4, figs. 2–6. Khirthar. About 1 mile SE of Bar Nana, Cutch; about 1 mile north of Lakhimirani, Cutch. (This is *N. laevigatus;* Nuttall's *N. laevigatus* is a new species.)

Nummulites mamilla (?) Fichtel and Moll. Nuttall, 1925a, pp. 445–446, pl. 27, figs. 1–3. Laki. Meting; near Murid (Bund Vera Plain); Fort Munro (Dehra Ghazi Khan).

Nummulites nuttalli, n. sp., Davies, 1927, pp. 266–271, pl. 18, figs. 3–4; pl. 19, figs. 7–9. Ranikot. Thal.

Nummulites nuttalli Davies. Davies, 1930b, p. 68, pl. 10, figs. 12–14. Ranikot. Samana Range. (Holotype G.S.I. No. 13544)

Nummulites nuttalli Davies, 1937, pp. 18–20, pl. 3, figs. 1, 2, 9; pl. 6, figs. 19–20; text fig. 1 (B). Ranikot. Nammal; Salt Range; Patala to Kalabagh; Kallar Kahar; Kala Chitta Range. (= *Operculinoides nuttalli*). According to Caudri (1944), this represents a new genus, *Ranikothalia*.

Nummulites nuttalli Davies var. *kohaticus*, n. var., Davies, 1927, p. 269, pl. 19, figs. 1–6. Ranikot, Thal.

Nummulites obtusus Sowerby. D'Archiac and Haime, 1853, pp. 122–123, pl. 6, fig. 13. Khirthar. Sind.

Nummulites obtusus Sowerby. Carter, 1853, p. 170, pl. 7, figs. 13–14. Khirthar. Valley of Kelat; Sind.

Nummulites obtusus Sowerby. Nuttall, 1926b, pp. 137–138, pl. 2, fig. 10; pl. 3, figs. 1–2. Khirthar. West of Laki, Sind; in the range SE of Damach, Thana Bula Khan taluqa, Karachi dist., Sind; Kalu Kushtak Nala, Bugti Hills, Baluchistan; Mardan Nala, Mula River, Kelat

State; west and northeast of Pabuni Chauki, Las Bela State; 1¼ mile north of Waghapadar (Waggerpudder), Cutch; Sham Plain, Bugti Hills, Baluchistan. (This is the microspheric form of *N. perforatus*.)

Nummulites obtusus Sowerby. Davies, 1940, p. 212, pl. 11, fig. 14. Khirthar. Kohat; Sirki Paila and Spintangi.

Nummulites planulatus (Lamarck). D'Archiac and Haime, 1853, pp. 142–144, pl. 9, figs. 5, 6.

Nummulites planulatus (Lamarck). Nuttall, 1926a, pp. 114–115, pl. 10, figs. 1–2; text fig. 1. Ranikot. Northeast of Petiani (G.S.I. No. G. 280/135); Jherruck (G.S.I. No. 280/124a and No. K./696).

Nummulites perforata (de Montfort). d'Archiac and Haime, 1853, pp. 115–120, pl. 6, figs. 1–12. Khirthar.

Nummulites perforatus (de Montfort). Nuttall, 1926b, pp. 138–139, pl. 2, fig. 9, Khirthar. Northeast of Pabuni Chauki, Las Bela State, Baluchistan.

Nummulites pinfoldi, n. sp., Davies, 1940, pp. 209–210, pl. 10, figs. 1–6, 8. Khirthar. Spintangi. Holotype, British Museum (N.H.) No. 35023.

Nummulites ramondi Defrance. Carter, 1861, p. 374, pl. 15, fig. 5. Khirthar. Wasna, near Broach.

Nummulites scabra Lamarck. D'Archiac and Haime, 1853, pp. 107–109, pl. 4, figs. 9–12. Eocene. Hala Range; Baluchistan; Cutch; Cherrapunji; Silhet.

Nummulites aff. *N. scabra* Lamarck. Nuttall, 1926b, pp. 136–137, pl. 2, figs. 5–8. Khirthar. West of Laki village, Sind; Kubba Shadi Sahid, 4 miles SE of Khairpur, Sind.

Nummulites sp. Carter, 1853, p. 169, pl. 7, figs. 9–10, Eocene. Schinde. (=*N. carteri*)

Nummulites stamineus, n. sp., Nuttall, 1926b, pp. 131–133, pl. 1, figs. 1–3. Khirthar. One mile south of Waghapadar (Waggerpudder), Cutch; 2 miles SW of Godhathad (Gothahad), Cutch; Kaly Nala, north of Lakh-ka-kot, Bugti Hills, Baluchistan.

Nummulites subatacicus Douvillé. Nuttall, 1925a, p. 445, pl. 25, fig. 7. Laki. Parts of Sind and Baluchistan.

Nummulites subatacicus Douvillé. Nuttall 1926b, p. 130. Khirthar. Pabuni Chauki, Las Bela State.

Nummulites sindensis (Davies). Davies, 1937, pp. 21–22, pl. 4, fig. 21. Ranikot. Nammal; Kala Bagh to Kallar Kahar; Kala Chitta Range. (=*Operculinoides sindensis*)

Nummulites subirregularis de la Harpe. Davies, 1937, pp. 27–28, pl. 3, figs. 6, 7, 11, 18. Laki: Salt Range.

Nummulites subirregularis de la Harpe. De Cizancourt, 1938, p. 15, pl. 1, figs. 5, 6. Laki. Gardez.

Nummulites sublaevigatus, n. sp., d'Archiac and Haime, 1853, pp. 106–107, pl. 4, fig. 8. Nari. Hala Range. (=*N. intermedius*)

Nummulites sublaevigatus d'Archiac and Haime. Medlicot and Blanford, 1879, p. 460, pl. 15, fig. 11. Nari. (=*N. intermedius*)

Nummulites thalicus, n. sp., Davies, 1927, pp. 269–271, pl. 20, figs. 1–4. Ranikot. Thal. Holotype, G.S.I. No. 13546.

Nummulites thalicus Davies, 1930b, pp. 68–69, pl. 10, fig. 11. Ranikot. Samana Range.

Nummulites thalicus Davies, 1937, pp. 20–21. Ranikot. Nammal to Kala Bagh in northern part of the Salt Range; Kala Chitta Range.

Nummulites thalicus Davies var. *gwynae*, n. var., Davies, 1927, p. 271, pl. 20, fig. 5. Ranikot. Thal.

Nummulites vicaryi, n. sp., d'Archiac and Haime, 1853, pp. 139–140, pl. 9, fig. 1. Eocene. Hala Range.

Nummulites wadiai, n. sp., Davies, 1927, pp. 273–274, pl. 21, figs. 17, 18, pl. 22, figs. 7–9. Ranikot. Thal.

Operculina canalifera, d'Archiac. D'Archiac and Haime, 1853, p. 182, pl. 12, fig. 1. Ranikot. Hala Range.

Operculina canalifera d'Archiac. Douvillé, 1916, pp. 36–37, pl. 15, figs. 6–8. Ranikot. Kampa Dzong, Tibet. (=*Operculinoides sindensis*)

Operculina canalifera d'Archiac. Nuttall, 1926a, pp. 117–118, pl. 11, figs. 1–2. Ranikot, Jherruck (G.S.I. No. G. 280/124a and K. 6/986); SW of Hilaia trigonometrical station. (=*Operculinoides sindensis*)

Operculina cf. *O. canalifera* d'Archiac. Davies, 1927, p. 276, pl. 20, figs. 11–13. Ranikot. Thal.

Operculina cf. *O. canalifera* d'Archiac. Davies, 1930b, p. 70, pl. 10, figs. 1–2. Ranikot. Samana Range.

Operculina cf. *O. canalifera* d'Archiac. Davies, 1937, pp. 35–36, pl. 5, fig. 5. Ranikot. Salt Range (Kala Bagh to Dandot); Kala Chitta Range.

Operculina aff. *O. canalifera* d'Archiac. Davies, 1937, p. 36, pl. 5, fig. 20. Ranikot. Majuchh Nullah.

Operculina hardiei, n. sp., d'Archiac and Haime, 1853, p. 346, pl. 25, fig. 6. Ranikot. Hala Range.

Operculina hardiei d'Archiac and Haime. Douvillé, 1916, pp. 37–38, pl. 15, fig. 9. Ranikot. Kampa Dzong, Tibet.

Operculina hardiei d'Archiac and Haime. Nuttall, 1926a, p. 118, pl. 11, figs. 3–4. Ranikot. Below trigonometrical station 685, near Leilan; SW of Hilaia trigonometrical station.

Operculina jiwani, n. sp., Davies, 1937, pp. 39–40, pl. 5, figs. 11–14, 16. Ranikot. Salt Range (Kala Bagh to Dandot; Kala Bagh to Chamil; Makarwal); Kallar Kahar; Rutuchha. Holotype, G.S.I. No. 15852.

Operculina patalensis, n. sp., Davies, 1937, pp. 38–39, pl. 5, figs. 6, 17, 18, 19, 26. Ranikot. Salt Range (Kala Bagh to Dandot); Kala Chitta Range; Hangu to Thal. Holotype G.S.I. No. 15847.

Operculina salsa, n. sp., Davies, 1937, p. 37, pl. 5, figs. 1, 3, 7, 10, 15. Ranikot. Salt Range (Kala Bagh to Dandot); Kala Chitta Range; Hangu to Thal; Kampa Dzong, Tibet. Holotype G.S.I. No. 15838.

Operculina sindensis, n. sp., Davies, 1927, pp. 274–276, pl. 19, figs. 10–13. Ranikot. Thal. (=*Operculinoides sindensis*)

Operculina subsalsa, n. sp., Davies, 1937, pp. 37–38, pl. 5, figs. 2, 4, 8–9. Ranikot. Salt Range (Kala Bagh to Dandot); Kala Chitta Range; Kampa Dzong, Tibet. Holotype G.S.I. No. 15843.

Operculina sp. Carter, 1853, pp. 167–168, pl. 7, figs. 3–4. Laki. Sind. (=*Assilina granulosa*)

Opertorbitolites douvillei, n. gen., n. sp., Nuttall, 1925a, pp. 447–448, pl. 27, figs. 4–6. Laki. Parri Nala, west of Bibi Nani, Bolan Pass, Baluchistan.

Orbitoides dispansus (Sowerby). Carter, 1861, pp. 446–451, pl. 16, fig. 1; pl. 17, fig. 1. Khirthar. Lukput, Cutch; valley of Kelat; Sind. (=*Discocyclina dispansa*)

Orbitoides mantelli, n. sp., Carter, 1853, p. 174, pl. 7, figs. 30–34. Scinde (Sind). (=*Lepidocyclina mantelli*)

Orbiculina malabarica (Carter). Carter, 1861, p. 462. Miocene. Kattyawar. (=*Archaias malabarica*)

Orbitolites asterifera, n. sp., Carter, 1861, pp. 451–452, pl. 17, fig. 3. Valley of Kelat. (=*Asterocyclina asterifera*)

Orbitolites complanatus Lamarck. D'Archiac and Haime, 1853, pp. 350–351, pl. 36, fig. 19. Hala Range.

Orbitolites complanatus Lamarck. Douvillé, 1916, pp. 43–44, pl. 16, figs. 1–2. Laki. Kampa Dzong.

Orbitolites pedunculata, n. sp., Carter, 1853, pp. 176–177, pl. 7, fig. 42. Schinde (Sind).

Orbitosiphon tibetica (Douvillé). Rao, 1944, pp. 97–99, pl. 1, figs. 1–3. Ranikot. Kampa Dzong, Tibet.

Pellatispira inflata Umbgrove var. *minor*, n. var., Rao, 1941, p. 15, pl. 1, figs. 3, 7. Khirthar. Tapti River area near Surat and Broach.

Pellatispira madarazi (Hantken) var. *indica*, n. var., Rao, 1941, pp. 13, 14, pl. 1, figs. 2, 5; pl. 2, fig. 3. Khirthar. Tapti River area near Surat and Broach.

Pellatispira orbitoidea (Provale). Rao, 1941, pp. 14, 15, pl. 1, figs. 1, 4, 6, 8; pl. 2, fig. 4. Khirthar. Tapti River area near Surat and Broach.

Rotalia newboldi, n. sp., d'Archiac and Haime, 1853, p. 347, pl. 36, fig. 17. Hala Range (in part=*Lockhartia haimei*).

Rotalia trochidiformis Lamarck. Davies, 1932, pp. 416–418, pl. 3, figs. 4, 5, 7. Laki.

Sakesaria cotteri, n. gen., n. sp., Davies, 1937, pp. 49–50, pl. 7, figs. 18, 21–24; text fig. 2. Laki. Salt Range; Nurpur; Choa Saidan Shah; Dandot; Manhaiala. Holotype G.S.I. No. 15878.

Siderolites miscella (d'Archiac and Haime). Douvillé, 1916, p. 38, pl. 15, figs. 4–5. Ranikot. Kampa Dzong, Tibet. (=*Miscellanea miscella*)

Siderolites miscella (d'Archiac and Haime). Nuttall, 1926a, pp. 116–117, pl. 10, figs. 5–6; text fig. 1. Ranikot. NE of Petiani (G.S.I. No. G. 280/135); southwest of Hilaia trigonometrical station; 5¼ miles southeast of Meting. (=*Miscellanea miscella*)

Siderolites miscella (d'Archiac and Haime). Davies, 1927, pp. 277–278, pl. 20, fig. 9; text figs. 1–3. Ranikot. Thal. (=*Miscellanea miscella*)

Siderolites stampi, n. sp., Davies, 1927, p. 278, pl. 21, figs. 1–8. Ranikot. Thal. (=*Miscellanea stampi*)

NOTES ON LARGER FORAMINIFERA

No less than 127 species and varieties of larger Foraminifera referred to 27 valid genera have been reported from the tertiaries of the Indian region. Of these, 85 species and varieties and seven genera are new.

Nummulites *spp.*—Sowerby (1837–40) described *N. acutus* and *N. obtusus* from Cutch which were later redescribed by Nuttall (1926b). D'Archiac and Haime (1853) referred to this genus 16 species of which only four (*N. obtusus*, *N. beaumonti* d'Archiac and Haime, *N. vicaryi* d'Archiac and Haime, and *N. carteri* d'Archiac and Haime) belong to this genus.

N. miscella d'Archiac and Haime is a *Miscellanea* and *N. exponens* d'Archiac and Haime, *N. leymeriei* d'Archiac and Haime and *M. spira* de Roisy belong to the genus *Assilina*. Nuttall (1926b) who revised d'Archiac and Haime's collection considers *N. lyelli* d'Archiac and Haime synonymous with *N. gizenhensis* Forsk; *N. sublaevigatus* d'Archiac and Haime with *N. intermedius; N. lucasana* Defrance with *N. perforatus* (megalospheric form of *N. obtusus*); *N. biarritzensis* d'Archiac and Haime with *N. atacicus;* and *N. garanensis* Joly and Leymerie with *N. fichteli* (megalospheric form of *N. intermedius*). Specimens referred by d'Archiac and Haime to *N. ramondi* Defrance, *N. scabra* Lamarck and *N. guettardi* d'Archiac and Haime were considered by Nuttall to be young forms of *N. atacicus*, *N. acutus* and *N. subatacicus*, respectively. Carter (1853, 1861) reported seven species of *Nummulites;* three (*N. irregularis* Carter, *N. kelatensis* Carter and *N. broachensis*) of these being valid species. Carter's *Nummulites* sp. ? was later described by d'Archiac and Haime as *N. carteri*. Carter's *N. acuta ?* Sowerby is the same as *N. intermedius*. Forms referred by Carter to *N. biarritzensis* were considered by Nuttall (1926b) to belong to either *N. atacicus* or *N. stamineus* and *N. ramondi* Defrance to *N. atacicus*. Vredenburg (1906) described a new species, *N. douvillei*, from Cutch which is a synonym of *N. acutus*. Nuttall (1926b) reported 14 species, two (*N. stamineus* and *N.*

maculatus) of them being new, from the lower and middle Khirthar series of western India. Nuttall's *N. maculatus* is the real *N. laevigatus* (Bruguiere's sp.) while the form reported by him as *N. laevigatus* (Bruguiere) is a new species. Davies (1937) recorded nine species of *Nummulites* from the Punjab Salt Range Eocene, one (*N. lahirii*) being new. Three of these (*N. nuttalli*, *N. thalicus* and *N. sindensis*) belong to the genus *Operculinoides*.

Alveolina *spp.*—There are eight valid species of *Alveolina* in the tertiaries of the Indian region more often referred to the genus *Fasciolites*. Five of these (*A. javana*, *A. lepidula*, *A. ovicula*, *A. subpyrenaica* and *A. vredenburgi*) are quite distinct but there has been some confusion in the identification of *A. elliptica*, *A. oblonga* and *A. ovoidea*.

A. elliptica was originally described by Sowerby (1837–40) from Wage-ke-Pudda (Waggerpudder) and Baboa Hills in Cutch from specimens collected by Captain Grant. Owing to the description being very brief and the lack of information as to the internal characters, several species of *Alveolina* of approximately the same size have been placed in this species. Carter (1853, 1861) incorrectly referred to this species Alveolinae from near Hydrabad which, according to Nuttall (1926a, b), are *A. subpyrenaica* Leymerie. D'Archiac and Haime (1853) and Parker and Jones (1861) incorrectly grouped Sowerby's *A. elliptica* and Carter's identification of this species as synonymous with *A. ovoidea* d'Orbigny, which by itself is a distinct species. Fedden (1870) referred Sind species of Alveolinae to *A. elliptica* Sowerby as the same as *A. ovoidea* d'Orbigny and *A. oblonga* d'Orbigny.

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NOTE:

Three articles, two by Gill (1953a and b) and another by Cole (1953) have been published while this manuscript was with the printers. Gill describes the following new species and varieties:

Assilina granulosa (d'Archiac) var. *chhumbiensis*, n. var., Gill, 1953a, pp. 839–840, pl. 89, figs. 1, 2, 4, 5. Laki. Lower Bhadrar beds of the Bakrala Ridge and the eastern Salt Range. Cotypes, British Museum (N.H.) P 41507, P 41520.

Assilina subdaviesi, n. sp., Gill, 1953a, pp. 838–839, pl. 91, figs. 5, 6. Laki. Bhadrar beds, Salt Range. Holotype, British Museum (N.H.) P 41544.

Assilina daviesi de Cizancourt, 1938. Gill, 1953a, pp. 837–838, pl. 89, figs. 6–13. Laki. Bhadrar beds, Salt Range.

The following forms are illustrated:

Assilina granulosa d'Archiac and Haime. Gill, 1953a, p. 839, pl. 89, fig. 3. Laki. Bhadrar beds, Salt Range.

Nummulites aff. *N. atacicus* Leymerie. Gill, 1953a, pp. 836–837, pl. 88, figs. 1–6, 8. Laki. Bhadrar beds, Salt Range. (The author discusses the Laki and Khirthar variants of this species under "*Nummulites* aff. *N. atacicus*" on pages 836 and 837. Figure 4 on page 837, which is a part of the discussion refers to dimensions and whorl numbers of "*N.* cf. *atacicus*." He states in footnote 2, on page 837, "Mr. Eames' opinion is that the Kirthar forms figured here [pl. 88, figs. 11 and 13] are a thin-edged variant of *Nummulites obtusus* var. *uranensis* [De la Harpe]." Plate 88 illustrates only figures 1–10. The author probably means figures 9 and 10 which are labelled"? *Nummulites atacicus* Leymerie." If the Khirthar

forms represent variety *uranensis*, they should be referred to *Nummulites perforatus* d'Orbigny var. *uranensis* de la Harpe, 1883, although it is generally recognized that *N. perforatus* is the megalospheric form of *N. obtusus*).

Rotalia trochidiformis Lamarck. Gill, 1953a, pp. 840–841, pl. 90, figs. 1–12.

Cole (1953) admirably sets up the criteria for the recognition of the genera (*Miscellanea*, *Camerina*, *Operculinoides* and *Operculina*) which have been confused in the Indian literature. It is of interest to note that like the present writer, Cole does not recognize *Ranikothalia* Caudri (type species *Nummulites nuttalli* Davies) as a valid genus and includes it in the synonymy of *Operculinoides* Hanzawa.

Gill (1953b) describes the following new species:

Assilina daviesi de Cizancourt var. *nammalensis*, n. var., Gill, 1953b, p. 82, pl. 13, figs. 1–5. Laki. Salt Range; Kohat dist. British Museum (N.H.) cotypes P. 41474, P. 41476.

Assilina laminosa Gill, n. sp. Gill, 1953b, p. 83, pl. 13, figs. 14–17. Laki. Salt Range; Dhulian Oilfield. British Museum (N.H.) cotypes P. 41487, (Attock Oil Co. No. L. 396).

Assilina sublaminosa Gill, n. sp. Gill, 1953b, pl. 13, figs. 18, 19. Laki. (Megalospheric form of *A. laminosa*) British Museum (N.H.) holotype P. 41491.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 195–203, PLS. 21, 22, 1 TEXT FIG., MARCH 1954

AN EOCENE FAUNA FROM THE CATHEDRAL BLUFFS TONGUE OF THE WASHAKIE BASIN, WYOMING

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ABSTRACT—An analysis of a small but diagnostic fauna from the Eocene sediments of the Washakie Basin, Wyoming, is presented. The suggestion is made that the fauna may be placed, in time, between the Lost Cabin zone, as represented in the Wind River Basin, and the fauna present in the Black's Fork zone of the Bridger Basin.

A new species of Eocene anaptomorphid primate is described and the systematic position of *Hyrachyus* cf. *H. modestus* is discussed.

INTRODUCTION

THE upland topography of the Rocky Mountains is interrupted in Colorado, Wyoming, and Utah by the Wyoming Basin composed of several well delineated structural depressions.[1]

South of the Wind River Basin and west of the Rawlins Hills the region is divided into three physiographic basins. The Great Divide Basin, an area of internal drainage over 4,000 square miles in extent, is situated south of the Antelope Hills and Green Mountains and, because of the red color of the soil derived from the underlying Tertiary formations, the name Red Desert has also been used to designate this area. The Bridger Basin, west of the Great Divide Basin and separated from it by the northern extension of the Rock Springs Dome and Leucite Hills, is a structural depression drained by the Green River. The Washakie Basin, an area of internal drainage about 3,000 square miles in extent, lies south of the Great Divide Basin and east of the Bridger Basin. It is bounded on the north by a broad structural swell and on the west by the Rock Springs Dome, while along its southern margin the Washakie Basin terminates at the northern flank of the Uinta Mountains. The westernmost cuestas of the Sierra Madre and Muddy Creek, a tributary of the Little Snake River, form the eastern boundary.

The general form of the Washakie Basin is analogous to three nested saucers each being smaller than the one below. The rims represent the steep, outward facing cuestas whose scarps rise from a few hundred to over 1,000 feet above the surrounding country.

The lowest escarpment is composed of the Hiawatha member of the Wasatch formation[2] and the lower Tipton tongue of the Green River formation. To the north only the Tipton tongue has topographic expression but along the eastern rim between Dad and Baggs, Wyoming, the greater part of the escarpment is formed by the red and white banded sediments of the Hiawatha member. The maximum relief of the scarp is 400 feet in the vicinity of Baggs and is locally exceedingly dissected forming finely textured badlands.

The middle cuesta extends almost around the entire basin and is formed of the Cathedral Bluffs tongue of the Wasatch formation and the lower part of the Laney shale member of the Green River formation. Except along the western part of the basin the Cathedral Bluffs tongue, more brilliantly red than the underlying Hiawatha, is eroded

[1] Physiographic names are those used by Fenneman, "Physiography of western United States," McGraw-Hill, 1931, 534 pp.

[2] It is realized that a tendency has existed to call all red-banded fluviatile sediments of the Rocky Mountain Intermountain Basins "Wasatch" and to assume that they were deposited contemporaneously. When early Eocene fossils were found in some of the formations "Wasatch" came to mean early Eocene time as well as representing lithic units. Further studies indicated that, while some of the formations were Eocene others were not and many of the units did not seem to be contemporaneous. Perhaps the confusion inherent in the term could be avoided by eliminating the name "Wasatch" but such stratigraphic revision is beyond the scope of this paper and the Cathedral Bluffs tongue as well as the Hiawatha member will be, for convenience, included as subdivisions of the Wasatch formation.

into badlands which to the southeast, in the vicinity of Cherokee Ridge, are over 1,200 feet high and form an almost impassable barrier to the interior of the basin.

Stratigraphically as well as topographically the highest unit within the central portion of the basin is the Washakie formation of Bridgerian age. The lower part of the Washakie formation, containing beds of massive sandstones, forms the uppermost cuesta.

The upper part of the Washakie formation has been eroded into a long ridge, named Mammouth Buttes, which is convex toward the north. Haystack Mountain, marking the eastern end of this east-west ridge and having an elevation of 7,689 feet, is the highest point in the basin. Westward from Haystack Mountain the ridge gradually diminishes in height until it meets the surrounding lowlands along the western border of the structural basin.

South of this ridge the Washakie formation is eroded into numerous isolated buttes decreasing in height toward the geographic center of the basin.

Studies leading to the present knowledge of the stratigraphy of the Washakie Basin and the geologic history of southwestern Wyoming were begun by Hayden (1873) eighty-four years ago when he named the "Washakie group" and regarded it as middle Tertiary. In 1870, Hayden described outcrops of the "Washakie group" near the center of the Washakie Basin along the Overland Stage Trail and noted that "Fragments of turtles and other vertebrate remains are not uncommon."

Following this discovery of vertebrate fossils in the badlands of the Washakie Basin both Cope and Marsh maintained collecting parties in the area for several seasons. Very little except descriptions of vertebrate material was subsequently published by Marsh, but Cope, in 1882, gave good accounts of his explorations in the vicinity of Haystack Mountain where he found the excellent type skull of *Loxolophodon cornutus*.

In 1878, a Princeton University expedition under the leadership of John B. McMaster secured a small collection of vertebrate fossils from the upper part of the "Washakie group." Since the Princeton expedition, there have been three collecting expeditions sponsored by the American Museum of Natural History whose work was confined to the Washakie formation.

The collections secured by the various parties from the Washakie formation were summarized by Granger (1908) when he suggested, " . . . they tend to show that faunally the lower Washakie corresponds with Bridger C and D, Middle Eocene, and the upper Washakie corresponds with the Uinta A and B, Upper Eocene."

The first major revision of the "Wasatch" of the Washakie Basin since King (1878) had named and described the "Vermillion Creek Group," was proposed by Schultz in 1920. He subdivided the upper "Wasatch" into the Tipton tongue and Cathedral Bluffs and included these units as well as the overlying Laney shale as members of the Green River formation. In 1924, Sears and Bradley recognized that the Cathedral Bluffs was a northward thinning tongue of the Wasatch formation.

In 1930, Nightingale proposed the name Hiawatha for " . . . that member of the Wasatch formation below the Cathedral Bluffs and Tipton tongue."

Aside from the well-known fauna from the Washakie formation, little is known concerning Eocene vertebrates from the Washakie Basin. Wasatchian animals have been reported as occurring in pockets along the eastern margin of the basin in the Hiawatha member. This fauna has been referred to as the "Dad local fauna" from its occurrence near the postal station of that name and serves to date the Hiawatha member. (Wood, H. E., et al., 1941, p. 18.) Collecting in the Cathedral Bluffs tongue has been neglected and in the past the unit has generally been regarded as being barren of identifiable remains.

Wood, et al. (1941) have, on the basis of stratigraphic relations to the underlying and overlying Green River sediments, placed the lower part of the Cathedral Bluffs tongue in the Wasatchian while the upper part was regarded as Bridgerian.

ACKNOWLEDGMENTS

The writer was fortunate in securing a small but diagnostic collection of vertebrate fossils from the eastern outcrop of the Cathedral Bluffs tongue. This will be dis-

cussed in the present paper and will aid in corroborating the stratigraphic evidence of the age of the Cathedral Bluffs tongue of the Wasatch formation.

The field work for the present study was done during the summers of 1949 and 1950 and was made possible by grants from the Princeton University Scott Fund. The stratigraphic and paleontological problems of the Washakie Basin were suggested by Dr. Glenn L. Jepsen, to whom the author is deeply grateful for his friendly and valuable counsel.

Mr. R. V. Witter and Mr. F. Goto have helped generously in the preparation of the fossil material.

It is a pleasure to acknowledge the assistance and friendship of Mr. William Harrup during the 1949 field season and of Dr. Minchen Chow during the summer of 1950.

I wish to thank Mr. L. A. Gimbrede, Assistant Professor of Geology at Texas Agricultural and Mechanical College, for preparing the photographs used in this paper.

STRATIGRAPHY AND PALEONTOLOGY

Marsupialia
Peratherium cf. *P. marsupium*
Insectivora
Nyctitherium sp.
Tillodontia
Trogosus cf. *T. latidens*
Primates
Absarokius witteri, n. sp.
Notharctus sp.
Rodentia
Ishyromyidae
Carnivora
Viverravus gracilis
Didymictus cf. *D. altidens*
Condylarthra
Hyopsodus paulus
Perissodactyla
Orohippus sp.
Eotitanops sp.
Hyrachyus modestus
Artiodactyla
Microsus sp.
Sarcolemur sp.

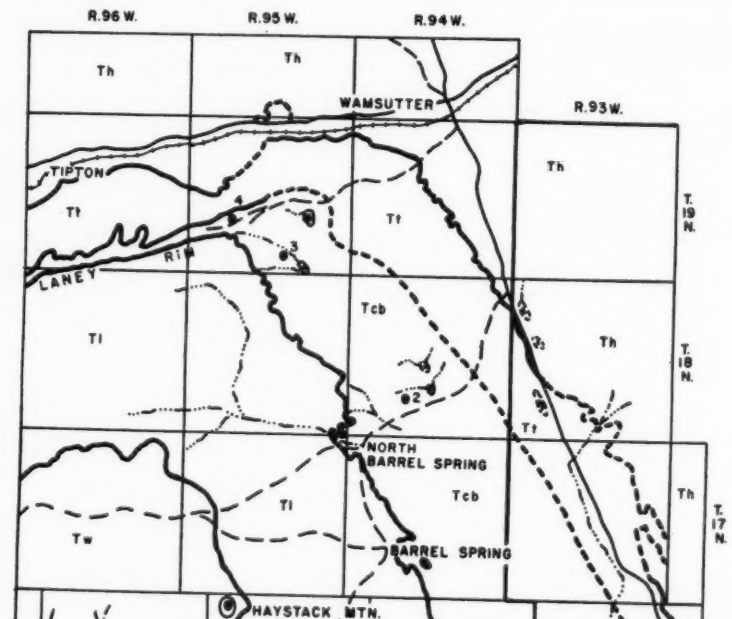
Fossils in the Cathedral Bluffs member are exceedingly scarce and, in the isolated pockets where specimens are to be found, the remains consist almost entirely of single teeth and small fragments of skeletal material. The entire circular outcrop of the unit was investigated but productive localities were discovered only along the eastern margins of the Washakie Basin. Although several fragmentary specimens were collected from the brilliant red and green mudstones, the most common occurrence of specimens was in two small arkosic sand lenses fifty feet long.

The distribution of productive lenses is unexplainable on the basis of discernible lithologic environments at the place of deposition, for the lithology of the Cathedral Bluffs is apparently the same around the circumference of the basin.

Most fossils from the Cathedral Bluffs tongue are of the smaller mammals, notably rodents and condylarths. This characteristic is in contrast to the fauna of the overlying Washakie formation where the larger perissodactyls are more commonly found and, to a lesser extent, in the underlying Hiawatha member. Perhaps the biocoenose of the Cathedral Bluffs is representative of a more forested area while the depositional environment of the sediments as interpreted from the lithology is more deltaic.

Of the twelve faunal elements listed, six seem to be diagnostic of the Bridgerian and are well-known from strata of that age in the Bridger basin. Tillotheres that have reached the evolutionary stage of the form which is represented in the Cathedral Bluffs collection by an isolated last upper molar herein referred to *Trogosus* cf. *T. latidens* (identification made by C. Lewis Gazin) are known throughout the fossiliferous horizons of the Bridger formation whereas the group is represented in the early Eocene sediments by the relatively unspecialized form *Esthonyx*. Although the group is in need of further study, the evolutionary trend of the tooth structures seems to be clearly demonstrated and, if this is the case, the presence of this advanced tillothere in the Cathedral Bluffs member indicates a provincial middle Eocene age for the enclosing strata. *Trogosus* cf. *T. latidens* together with such other adequately known genera and species as *Viverravus gracilis*, *Hyopsodus paulus*, *Orohippus*, *Microsus*, and *Sarcolemur* date the Cathedral Bluffs

fauna as Bridgerian. This conclusion is supported by the rodent specimens submitted to A. E. Wood, who has referred one form to a new species of *Microparamys*, of the Paramyidae and, although the genus ranges from the Gray Bull formation to the Uinta formation, the specimen in question seems closest to *M. minutus* (Wilson) from the Bridger formation. In spite of the fact that the specimen is most nearly related to a Bridgerian form, Wood makes the interesting statement that it is, "not too far advanced from a new species from the Lysite" (Albert E. Wood, personal communication). A second group of specimens was referred by Wood to a new genus of Bridgerian paramyids. A considerable number of isolated teeth belonging to sciuravids were also sub-



INDEX MAP OF THE EASTERN WASHAKIE BASIN

0 5 10 miles

Modified After Brodley, W. H (1945)

Th – Hiawatha membr. (Wasatch)
Tf – Tipton tongue (Green Riv. fm.)
Tcb – Cathedral Bluffs membr. (Wasatch)
Tl – Laney sh. (Green Riv. fm.)
Tw – Washakie fm.
●2 – Fossil Localities

FIG. 1

mitted and, while sciuravids are known from the late Wasatchian, they are most common in Bridgerian strata.

In summary, Wood believes that the specimen of *Microparamys* and the isolated sciuravid teeth suggest Bridgerian age, and that the second group is almost a certain indication of Bridgerian age.

Dr. Wood suggests that the rodent fauna indicates a Black's Fork age, perhaps early Black's Fork, for the Cathedral Bluffs tongue. This suggestion is supported by the presence in the fauna of *Hyopsodus paulus*, *Microsus*, and *Sarcolemur*.

While several of the specimens are not conclusive for faunal correlation, there is still a third element which may serve more precisely to locate stratigraphically the Cathedral Bluffs fauna. The genus *Absarokius*, represented in the collection by *A. witteri*, n. sp., has been found only in the Lysite and Lost Cabin faunal zones and, despite the rarity of the genus, it may have some bearing on the correlation of the Cathedral Bluffs member.

The presence of *Didymictus* cf. *D. altidens* in the Cathedral Bluffs tongue stresses the relationship of the fauna to that of the Lost Cabin zone. The species is represented in the collection by a single lower right first molar and while the paraconid and metaconid of the tooth are closer together than in the type specimen (AMNH No. 4792) it most assuredly represents an animal more nearly related to *Didymictus* than to any of the Bridgerian miacids. *Eotitanops* and *Hyrachyus modestus* are found in both the late Wasatchian and early Bridgerian and serve to relate the Lost Cabin and Bridger B faunal zones. As discussed below, the two specimens of *Hyrachyus modestus* from the Cathedral Bluffs tongue are less specialized in several respects than most of Bridgerian age. The Washakie and Bridger Basins were geographically close and probably connected during deposition of the Eocene strata, although the two faunas differ in minor aspects. These differences tend to ally the fauna with that of the early Eocene.

If these structural differences should prove significant, the Cathedral Bluffs fauna may be placed between the Lost Cabin level and Bridger B, perhaps being represented in the Bridger Basin by the rarely fossiliferous sediments of Bridger A. This conception of the faunal age is supported by the field relationships of the Cathedral Bluffs tongue which is separated by several hundred feet of dominantly lacustrine deposits from the lower Washakie formation that contains a fauna related to that of Bridger C (lower portion of the Twin Buttes zone).

The equivalence of the Cathedral Bluffs tongue with the dominantly fluviatile sediments underlying the Bridger formation in the Bridger Basin has not been established. Gazin (1952, p. 13) suggests that the New Fork tongue, exposed in the western portion of the Bridger Basin, represents the upper stage of the Lost Cabin Wasatchian, the fauna being characterized by *Meniscotherium chamense*, *Hyrachyus* spp., and *Bathyopsis*. According to the faunal list prepared by Gazin (1952, p. 8), *Lambdotherium popagicum* is the most abundant species represented in the collection from the North Fork while such typically Wasatchian forms as *Heptodon*, *Meniscotherium*, *Esthonyx*, and *Ambloctonus* cf. *A. major* were also found. In spite of the relatively large number of isolated teeth found, none of the genera, with the exception of *Hyrachyus* and *Hyopsodus*, listed as occurring in the North Fork, have been identified in the Cathedral Bluffs tongue.

Due to the lack of relationship between the two faunas and the number of Bridgerian elements present in the Cathedral Bluffs tongue the suggestion is tentatively made that the North Fork is equivalent to at least the upper part of the Tipton tongue of the Green River formation underlying the Cathedral Bluffs tongue in the Washakie Basin.

SYSTEMATICS

Order PRIMATES

Family ANAPTOMORPHIDAE

Genus ABSAROKIUS

The genus *Absarokius* was erected by Matthew in 1915 to include several species of small Eocene primates similar to the genus *Tetonius* but differing from it in significant characteristics. Although no specimens of *Absarokius* have been reported in which the teeth in front of P_3 are preserved, the dental formula suggested by

the teeth present and the alveoli of the anterior teeth was believed by Matthew to be $\frac{1\text{-}1\text{-}3\text{-}3}{}$.

The lower molars are similar to those of *Tetonius* but the low labial cusps are set farther towards the midline of the tooth. The anterior molars are quadrate while the relatively smaller M_3 is elongate. The paraconid is separate on M_1 and is distinct but joined to the metaconid by a ridge on M_2–M_3. The talonids of the molars are basined and a hypoconulid and entoconulid are present on M_1–M_2, being less distinct and very small on the last molar.

Perhaps the most characteristic tooth is the relatively massive P_4 which figuratively looks as though it had once been in a plastic state and had drooped over the labial margin of the jaw. The small P_3 also is characterized by a tendency toward overhanging and, in addition, acts as a buttress against which the large P_4 rests.

The mandible is deep and short and a crowded condition of the alveoli in front of P_3 is apparent.

ABSAROKIUS WITTERI Morris, n. sp.
Plate 21, figure 2

Holotype.—Princeton University No. 14972, left mandible containing P_3, P_4, M_2, M_3 and anterior alveoli.

Distribution.—Cathedral Bluffs tongue of the Wasatch formation, sec. 33, T. 19 N., R. 95 W., Sweetwater County, Wyoming.

Generic characters.—P_3, P_4, M_2, and M_3 have the diagnostic characters of the type species, *Absarokius abbotti* (Loomis), 1906.

Specific characters.— P_3 inflated but less so than P_4. The anterior portion of the tooth is undercut, thus producing a flat inclined face that slants towards the anterior root. P_4 is massive and lacks the relatively blade-like ridges apparent on the anterior cusp of P_4 of *A. abbotti* and *A. noctivagus*. The anterior cusp is bunodont, and behind it, lingual to the midline and near the rear of the crown, is a small cusp, perhaps the hypoconid. The inferior labial border of P_4 is inclined towards the posterior root. M_2 and M_3 have basined talonids which are crenulated. M_3 has a small connate paraconid.

Absarokius witteri is larger than either *A. abbotti* or *A. noctivagus*. The type of *A. noctivagus* (AMNH No. 16501) shows a more marked anteroposterior compression of the tooth row than *A. abbotti* or *A. witteri*. In the two known specimens of *A. noctivagus* (AMNH Nos. 15601 and 15602) M_2–M_3 show a distinct labial bulge; this tendency is less apparent in *A. abbotti* (AMNH Nos. 14673, 14672 and 15528) and *A. witteri*.

Were it nor for the difference in the front teeth, this genus might perhaps be regarded as within the range of variation suggested by specimens of *Tetonius*.

Matthew (1915, p. 465) recognized this similarity and stated, "Were it nor for the single specimen of *A. abbotti* in which the alveoli of the front teeth are preserved, I should regard the three species *homunculus* (*Tetonius*), *abbotti* and *noctivagus* as three stages of a generic series. It is possible that this is really the case, and the *abbotti* lower jaw is abnormal." The specimen of *A. abbotti* to which Matthew referred is AMNH No. 14673 and has four or possibly five alveoli preserved in front of P_3 whereas the genus *Tetonius* would be characterized by two. Fortunately, *A. witteri* also has the anterior alveoli preserved and they also

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EXPLANATION OF PLATE 21

FIG. *1*—*Trogosus* cf. *T. latidens* (Marsh), right M^3 (Princeton University No. 14971), external and crown view, ×1. (p. 197)

2—*Absarokius witteri*, n. sp., part of left lower jaw with P_2, P_4, M_2, M_3 and anterior alveoli (Princeton University No. 14972), external and crown view, ×2. (p. 200)

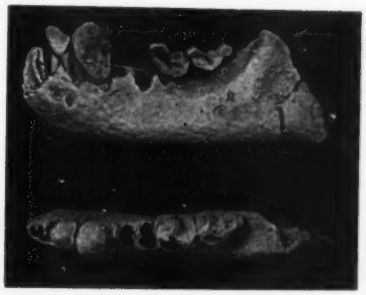
3—*Hyrachyus modestus* (Leidy), left P^2 (Princeton University No. 16015), exterior and crown view, ×1. (p. 201)

4—*Hyrachyus modestus* (Leidy), right P^3 (Princeton University No. 16105), exterior and crown view, ×1. (p. 201)

5—*Hyrachyus modestus* (Leidy), left M^1 and M^2 (Princeton University No. 16015), exterior and crown view, ×1. (p. 201)

6—*Hyrachyus modestus* (Leidy), part of left lower jaw with P_1, P_2, P_4 and M_3 (Princeton University No. 16108), exterior and crown view, ×1. (p. 201)

1



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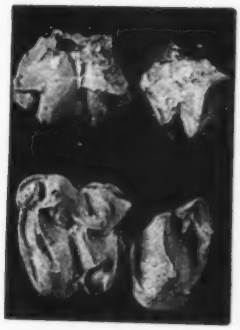
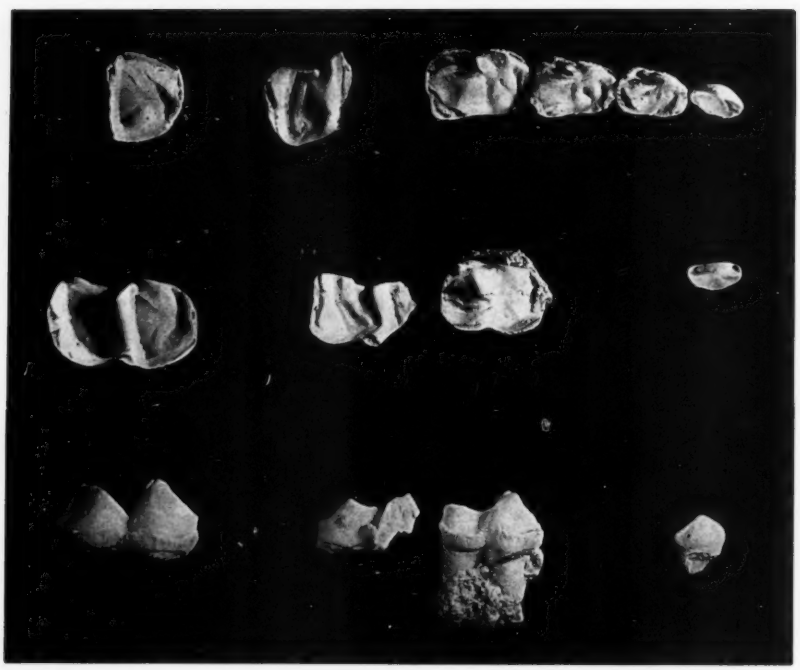


5

6

Morris, Eocene vertebrate fauna from Wyoming

1



2

Morris, Eocene vertebrate fauna from Wyoming

TABLE 1—TOOTH MEASUREMENTS OF *Absarokius* SPECIES. DIMENSIONS REPRESENT MAXIMUM MEASUREMENTS

	Length P_4 (mm.)	Width P_4 (mm.)	Height P_4 (mm.)	Length M_3 (mm.)	Width M_3 (mm.)
Absarokius witteri, type (Princeton U. No. 14972)	3.51	2.90	4.10	3.20	2.10
Absarokius noctivagus, type (AMNH No. 15601)	3.59	2.75	3.60	2.43	1.69
Absarokius noctivagus (AMNH No. 15602)	2.55	2.50	4.15	(crown missing)	
Absarokius abbotti (AMNH No. 14672)	2.90	1.92	2.50	2.20	1.42
Absarokius abbotti, type (AMNH No. 14673)	2.90	2.40	2.90	2.15	1.75

number four or possibly five. As the alveoli are all of about the same size, the position of the canine is very doubtful and if, as seems to be the case, the alveoli represent at least four single rooted teeth, the dental formula given by Matthew for the genus is questionable.

This species is named in honor of its discoverer, Mr. Robert V. Witter, formerly preparator of vertebrate fossils at Princeton University.

Order PERISSODACTYLA
Family HYRACHYIDAE
Genus HYRACHYUS
HYRACHYUS cf. H. MODESTUS
Plate 21, figures 3–6; plate 22, figures 1 and 2

Prior to the recent work in the Washakie Basin, two specimens of a primitive form closely similar morphologically to *Hyrachyus modestus* (Leidy) had been found in the Wasatchian Lost Cabin formation (*Lambdotherium* zone, Osborn, 1929). The less complete of these two specimens was collected by Wortman in 1880 in the Bighorn Basin and consists of a partial jaw with right P_2–P_3 and the alveolus for P_1 and P_2 of the left side (AMNH No. 4887). The other specimen, AMNH No. 14886, was collected in 1909 in the Davis Ranch area of the Wind River Basin by George Olsen. This specimen consists of a number of loose teeth as follows: P_1–P_4, talonid of M_1, trigonid of M_3, right P_1, P_4, M_1, and M_3. According to Wood, it seems reasonably certain that the teeth belong to the same individual.

In the Cathedral Bluffs member exposed in the Washakie Basin, specimens of *Hyrachyus* are extremely rare although during the summer of 1949 a partial left lower dentition was collected from a channel deposit four miles west of Wamsutter, Wyoming. The specimen contains P_2, the alveoli of P_3, P_4, and M_1 (Princeton University No. 16108). In the following field season a second lower dentition was collected one mile east of North Barrel Spring consisting of M_1, M_2, and M_3 (Princeton University No. 16105), probably representing a young individual, as the teeth are relatively unworn. In 1950 the channel deposit which yielded the first specimen also yielded several upper teeth classifiable as *Hyrachyus* but it is doubtful that the two dentitions belong to the same individual although the size of the upper teeth is appropriate.

The evolutionary pattern exemplified by the teeth of the Hyrachyidae is similar, with minor exceptions, to that displayed by the perissodactyls generally. Among the hyrachyids there is a tendency for progressive anterior-posterior molarization of the

EXPLANATION OF PLATE 22

FIG. 1—*Hyrachyus modestus* (Leidy), part of left lower jaw with M_1–M_3 (Princeton University No. 16105), exterior and crown view, ×1. (p. 201)

2—*Hyrachyus modestus* (Leidy), part of lower jaw with P_1–P_4 (A.M.N.H. No. 14886), crown and exterior view, ×1. (p. 201)

premolars in both the upper and lower jaws, the first indications of which are the development of the protoloph and ectoloph. As the molar condition is reached, the protoloph tends toward a right angle connection with the ectoloph. In the premolars, the ectoloph is present but its primitive condition is demonstrated by the prominence of the paracone and metacone set closely together and towards the labial midline of the tooth. Later in the progression a posterior loph develops, connecting the metacone and metastyle. In the premolars of the Hyrachyidae the posterior metaloph becomes apparent on P_3 but is directed toward the midline of the protocone. In the molars the two lophs become more developed and not only tend to separate towards the anterior and posterior margins of the tooth but also to assume a more obtuse connection with the well-developed ectoloph although maintaining a smaller angle than is characteristic in the horse and titanothere groups. Even in the most primitive condition the members of the Hyrachyidae do not have a paraconid and the anterior of the tooth has, instead, a crescent-shaped ridge extending from the paraconid anteriorly to the lingual side of the tooth. The third and fourth lower premolars of this group have developed a hypolophid but, rather than being a transverse ridge as is characteristic of the molars, it is usually a longitudinal ridge directed toward the protoconid. On the true molars the anterior crescent is maintained but the hypolophid tends to extend as a blade from the hypoconid to the lingual side of the tooth. All of the premolars and molars including M_3 tend toward reduction and loss of the hypoconulid (Wood, 1934).

The specimens of hyrachyids collected in the Washakie Basin appear to have specific characters which closely relate them to *H. modestus* found at Horizon B of the Bridger formation in southwestern Wyoming and in the Huerfano of Colorado. These specimens, however, plus those found in the Wasatchian Wind River formation have certain attributes which mark them as being distinctive.

The complete left lower molar series is well preserved in Princeton University Mus. No. 16105. In the lower molar the lophs are well developed and appear to have reached the *H. modestus* stage in that the labial portions of the transverse ridges are directed quite noticeably towards the anterior and have not reached the more directly transverse stage as shown in the later Bridgerian hyrachyids. Of the last three molars M_3 is the most primitive and retains a distinct medial fold in the center of the transverse ridge of the hypolophid. It appears probable that this fold represents one of the last stages in the retention of the hypoconulid and, like that cusp, emerges from the large posterior cingulum. None of the specimens of *H. modestus* appears to have this cusp and the only other specimens displaying this characteristic are those two found in the Wind River formation and referred to as *H.* cf. *H. modestus* by Wood (1934). M_1 and M_2 of AMNH No. 14886 lack any significant trace of the hypoconulid and differ from those of *H. modestus* only in the presence of a small auxiliary style situated lingually between the hypoconid and protoconid. Princeton University Mus. No. 16108, a left lower dentition with the somewhat worn P_2, P_4, and M_1 preserved, presents something of an enigma in the light of the above-mentioned lower teeth. Both of the premolars, while worn, show little or no difference from those of *H. modestus* but M_1 is more primitive than in either *H. modestus* or the single specimen of *H.* cf. *H. modestus* (AMNH No. 14886) in which the talonid of M_1 is preserved. In this tooth, even though it is considerably worn, the posterior cingulum appears to have a rather broad connection to the transverse ridge of the hypolophid and if the tooth were restored to its original condition it would seem to present evidence for the presence of a still discernible hypoconulid.

The upper teeth found in the Washakie Basin are of interest in that they may represent the first upper teeth found of *H.* cf. *H. modestus*. The only primitive characteristic noted in these teeth is the small degree to which the paracone and metacone have been assimilated into the formation of the ectoloph. This is apparent not only on the right P^3 but on the left M^1 as well. All of the teeth found (left P^2, M^1, and M^2, right P^3, though not necessarily of the same individual) show the beginnings of the metaloph. This characteristic is generally pro-

gressive toward the last molars but the P^3 shows a much more extensive development of the metaloph than the others.

Certainly in such a group as the Hyrachyidae where the evolution of the group appears to be rectilinear in part (*H.* cf. *H. modestus*, Lost Cabin; *H. modestus*, Bridger B; *H. eximus*, Bridger C; *H. douglassi*, Uinta A; Wood, 1934) and in which the evolutionary changes are towards uniformity accomplished by progressive molarization of the premolars as well as similarity in the molars, it becomes extremely difficult to ascertain whether seemingly minor morphological structures are of sufficient taxonomic importance to justify the naming of a new species. One of the primary purposes of paleontology is to fill in the gaps of our knowledge concerning life in the geologic past and when these gaps are partially filled, be it only by single and fragmentary specimens, the difficulty of assigning taxonomic pigeon-holes to successively evolving populations becomes very real indeed.

Wood (1934, p. 199), in discussing the phylogenetic position of the Wind River specimens of *H. modestus* states, "It is, of course, quite likely that a better specimen would show specific differences from *H. modestus*. It seems safest, however, to await the discovery of such a specimen, rather than to saddle the literature with a new name on purely stratigraphic grounds, especially as it is perfectly possible that the separation might not be supported by further discovery. Neither of these specimens would make a satisfactory type specimen."

In view of the evidence available, the position and condition of the hypoconulid is an important taxonomic character of the perissodactyls and is, therefore, inherently important in the recognized phylogeny of the hyrachyids. The collected specimens of hyrachyids possessing a rudimentary hypoconulid were obtained from stratigraphic units adjacent in time (late Wasatchian, Lost Cabin formation and the early Bridgerian Cathedral Bluffs member), while specimens of *Hyrachyus* collected from units above the early Bridgerian completely lack the hypoconulid.

Despite the importance of this conclusion only specimens in which the last lower molars are preserved could be placed within the limits of a new species based on the presence of a rudimentary hypoconulid and, although this would not detract from the systematic position of the fossil, it would certainly limit its use in stratigraphic work. In view of this, the present writer believes that while the evolutionary level may be used, together with other faunal information, to ascertain the time relationships of the enclosing rock, the specimens in question should be relegated to *H. modestus*.

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NEW SPECIES OF *PLUMMERICRINUS*

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ABSTRACT—Two well-preserved crowns from the Francis shale (Missourian) of southeastern Oklahoma are described as *Plummericrinus striatus*, n. sp. Two forms common to the Wann formation (Missourian) of northeastern Oklahoma are described as *P. erectus*, n. sp., and *P. granulosus*, n. sp. A note is made of yet another form as *Plummericrinus* sp.

Genus PLUMMERICRINUS Moore and Laudon 1943

PLUMMERICRINUS STRIATUS
Strimple, n. sp.
Plate 23, figures 1, 2, 8

DORSAL cup truncate, bowl-shaped, with a shallowly depressed base. At mid-height of the cup, there is a pronounced outwardly directed flare. Interradial areas are depressed, and outer surfaces of RR curve into the interarticulating areas to form shallow valleys between the articulating facets.

IBB circlet is composed of five subhorizontally directed plates, covered mainly by the round proximal columnals. Five BB are of moderate size and have pentagonal outlines except for the posterior B and right posterior B which have hexagonal outlines. The width and length of the BB are approximately equal. Proximal portion of the basal circlet curves sharply under to form the sides of the basal concavity. The basal plates are mildly tumid.

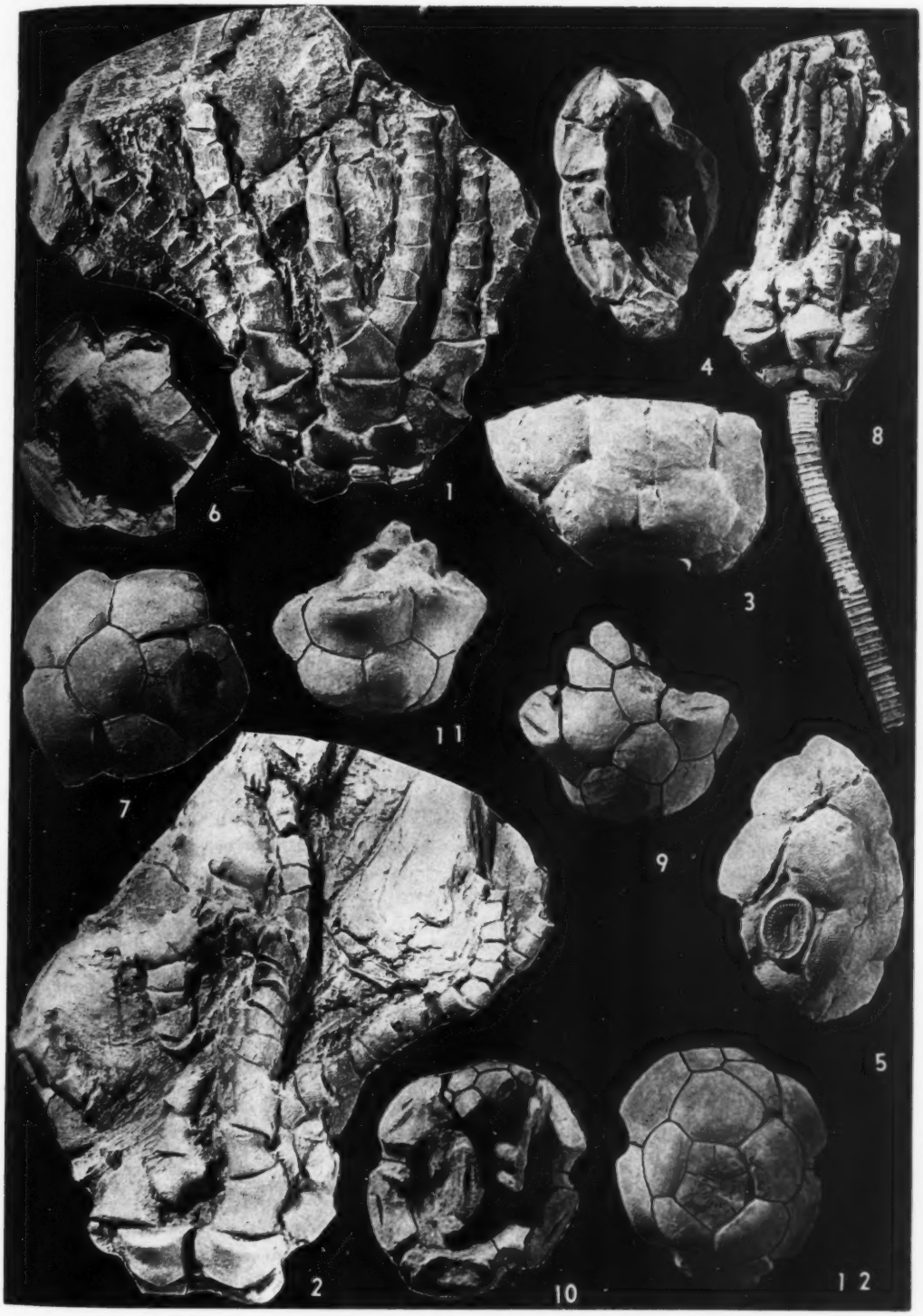
Five RR are wide plates with pentagonal outlines. As previously noted, strong furrows are present between adjacent RR, which continue into the summit area in such a manner as to divide the articulating facets. In addition there is a strong transverse curvature of each plate that is particularly pronounced in the distal portion and augments the scalloped appearance of the radial circlet. Outer ligament area is pronounced and has a lip-like appearance. The surface sculpture of the outer area does not cross the unpretentious outer marginal ridge. Fine crenellae are present on the outer ligament shelf. There is a prominent ligament pit furrow and the ligament pit is well defined. The transverse ridge is sharp crested, finely crenulate, and well elevated, particularly where it adjoins the ligament pit. Articular facets slope mildly outward and do not fill the distal faces of RR, as previously outlined.

Three large anal plates occupy the posterior interradius, anal X in contact with posterior B, RA obliquely placed to the right of anal X and in contact with right posterior B, and RX directly above RA. This is a normal or "primitive" arrangement.

The arms are long and slender, with strongly rounded exteriors. First primibrachials ($PBrBr_1$) are axillary in all rays and are of unequal length. The right posterior and left anterior PBrBr have a length of 6.0 mm., right anterior 5.2 mm., anterior 6.2 mm., and left posterior 6.3 mm. There is a mild median constriction and the distal extremity of PBr is acute. Secundibrachials (SBrBr) are cuneiform, the first two rather elongated. The long lateral side of each nonaxillary brachial has a small inner facet for the reception of a pinnule. Both

EXPLANATION OF PLATE 23

FIGS. *1*, *2*, *8*—*Plummericrinus striatus* Strimple, n. sp. Holotype; *1*, right anterior; *2*, left posterior, ×1.7; paratype; *8*, right anterior, ×1. (p. 204)
3–5—*Plummericrinus* sp. One specimen; *3*, right anterior; *4*, summit; *5*, base; ×2. (p. 207)
6, *7*—*Plummericrinus granulosus* Strimple, n. sp. Holotype; *6*, summit; *7*, oblique basal view; ×2. (p. 207)
9–12—*Plummericrinus erectus* Strimple, n. sp. Holotype; *9*, posterior; *10*, summit; *11*, anterior; *12*, base; ×2. (p. 206)



Strimple, New Pennsylvanian crinoid from Oklahoma

lateral sides are constricted but the short side more decidedly indented. There are no median ridges strictly speaking; however, the rays are marked by coalesced surface striations. These are occasionally in pairs, one passing to the succeeding brachial and the other to the pinnule. Second bifurcation of the arms takes place on the eighth to tenth SBr in all observed instances. A splay-toothed appearance is caused by the depression of the apices of axillary SBr. The articulating facets of the nonaxillary brachials possess a furrow that is comparable to the ligament pit furrow of radial articulation facets, as well as a ligament pit and a transverse ridge. Shallow muscle scars are present and the ambulacral groove has the appearance of a large, broad, intermuscular notch of a radial plate. On nonaxillary brachials, the ligamentous fossae are restricted to the side opposite the pinnule-bearing side. On axillary brachials, a regular development is present in each ray. The pinnular facet is obliquely placed on the inner-lateral edge, below the distal muscular facets. There is only one pinnule to each nonaxillary brachial, and it occurs on alternating sides of the arm. Viewing the brachials from the inner side discloses that they are hollowed out. The distal and proximal facets are like shelves, supported on each side by the incurved lateral sides of the plates.

The anal sac is well shown by the paratype, though it is not preserved to its distal extremity. Considerable effort was required to determine the number of plates comprising the tube because of its delicate nature and because of the soft matrix. The two series of large plates, shown to the left side by the illustration, are posterior in position. The left ray is in direct contact with RX. Another series of large plates which are not visible apparently make contact with the anal X. The rest of the tube is composed of four series of slightly smaller, more delicate, hexagonal plates. These smaller plates are not tumid. All of the tube plates are thin, particularly those of the anterior four rays. Depressions are found at the four corners of each plate, and in the larger posterior rays there are delicate slits along the lateral sides. Raised ridges that pass from one to the other are present on the plates of the "anterior" series but slit-like openings have not been observed between these plates. The structure indicates that the gut followed the posterior side to the distal termination of the sac where it recurved and passed down the anterior side. Under such circumstances the anal opening would be low on the anterior side.

The column is round, annulated and is composed of alternating expanded segments of different length and thickness. The larger segments are girdled by sharp rims and the intervening smaller columnals have more rounded rims. A large segment is usually followed by a short columnal, then by a larger segment which does not attain the full size of the first large segment. The next large segment does attain a size comparable to the first large segment. This unequal distribution is distinctive but does not occur in each and every series of five segments. There are about 28 short crenellae marking the articular surface of each columnal. The lumen is relatively small and has a pentalobate outline. There is no evidence that cirri were present on the observed columns.

Surface ornamentation consists of small pustules, or granulations, which tend to coalesce and form fine ridges in the upper portion of RR and continue the length of the arms. Granulations continue onto the upper part of the dorsal cup and arms but constitute a minority ornamentation in those regions where the longitudinally directed, fine ridges predominate.

Both the holotype and paratype are somewhat distorted by lateral compression and measurements are of necessity estimated. The dorsal cup is 16 mm. wide and 8 mm. high. The maximum length of the arms as preserved is 52 mm. The column is very slow tapering. More than 50 mm. of the stem is preserved in the paratype and it has a diameter of 4.0 mm. in proximal portion as against 3.8 mm. in lowermost portion.

Remarks.—The shape of the dorsal cup of *P. striatus* is closer to *P. mcguirei* (Moore) (1939) than to other described species. The surface decoration of *P. striatus* and lessened bulbosity of BB plates are sufficiently distinctive to provide ready separation from *P. mcguirei*. The arms of *P. mcguirei* are more massive and the brachials are different from those of the present species.

A distinctive characteristic of *P. striatus* appears to be the sharp rim-like girdles of the larger columnals. The column of *P. twenhofeli* (Moore) (1939) and *P. mcguirei* reflect the alternating expanded pattern of nodals and internodals, but neither of those species develops a sharp rim-like structure. In *P. twenhofeli*, the column is reported to be cirriferous, and in *P. mcguirei* no cirri or scars for attachment of cirri are reported. As previously noted, the preserved portions of columns in *P. striatus* lack cirri.

Occurrence.—The paratype was collected by Mr. Allen Braffham from the large crinoid colony discovered by Mr. Richard Alexander in the brick pit south of Ada, Oklahoma, in the Francis shale, Missourian, Pennsylvanian. The holotype was collected by Mr. Richard Alexander in a zone about one foot below the crinoid colony.

Types.—To be deposited in the U. S. National Museum.

Plummericrinus erectus
Strimple, n. sp.
Plate 23, figures 9–12

Dorsal cup truncate, bowl-shaped, with mildly convex base. At midheight of the cup there is a sharp outwardly directed flaring. Sutures are mildly impressed and, in distal portion of RR circlet, strong valley-like depressions are found. These groove-like depressions pass into the articulating areas and sharply separate the arm-articulating facets of the RR. They are more the result of strong transverse curvature of the radial plates than of depression of the adsutural areas. The result is a strongly splay-toothed appearance, especially impressive when the cup is viewed from above or below.

IBB circlet is broad, mildly upflared in attitude, pentagonal in outline, and is composed of five plates. Median portion of the disk is shallowly depressed and is occupied by an obconical stem cicatrix.

BB plates are large, pentagonal in outline although possessing six sides, with those of the posterior and right posterior each having an additional facet due to contact with anal X and RA respectively.

RR plates are wider than long and are outwardly directed. There is a strong transverse curvature as previously mentioned. A lip-like extension is formed in the outer ligament region, ligament pit furrow is well defined and ligament pit is deeply impressed. Transverse ridge is sharp and marked by fine crenellae. Articular facets slope outward. Muscle scars are shallow but well defined. Intermuscular notch is wide and very short.

The plates of the posterior IR are distinctive. There are three large elements within the boundaries of the cup proper which are in normal (primitive) arrangement. Anal X is followed by a large plate above and a small plate to the upper left. RX is followed by a large plate above and a small plate to the right above. There appears to have been a strong union between plates of the cup and the lowermost plates of the tube proper. Such a condition is often exhibited among various species of *Zeacrinites*.

Knowledge of the arms is restricted to the first few brachials. The PBrBr are axillary, constricted in midsection and are of unequal length. SBrBr have well rounded exteriors and are in zig-zag arrangement.

The anal tube and column have not been observed.

Surface areas are marked by minute pustules, or granules, which do not form a pattern. The holotype has a maximum width of 13.2 mm. (posterior to anterior), height of 7.9 mm. and width of IBB circlet 5.3 mm.

Remarks.—Possession of dorsal cups having deeply indented areas between the radial articulation facets is common to *P. striatus*, *P. mcguirei* and *P. erectus*. In both of the former species the base is concave and the IBB circlet relatively small. *P. erectus* has a mildly convex base with a large IBB circlet. *P. mcguirei* is usually represented by forms having more bulbous plates than those of the present species. *P. striatus* is more ornate than either of the two mentioned species.

Occurrence.—The hill, or mound, just west of the city limits of Bartlesville, Oklahoma; excavation in low hill about $\frac{3}{4}$ mile due west of the high school in Ochelata, Oklahoma (type locality); first shelf in the exposure located in E. $\frac{1}{2}$ sec. 25, T. 25 N., R. 12 E., Osage County, Oklahoma; Wann formation, Ochelata group, Missourian, Pennsylvanian.

Types.—Collected by the author and his wife, Mrs. Melba Strimple. To be deposited in the U. S. National Museum.

PLUMMERICRINUS GRANULOSUS
Strimple, n. sp.
Plate 23, figures 6, 7

This species is represented by a single incomplete dorsal cup. The cup is low, bowl-shaped, with IBB readily visible in side view. Five IBB are large plates forming a low disk. Five BB are hexagonal, with the exception of posterior B, and are mildly tumid. Five RR are pentagonal, wider than high and are tumid. At the summit of the cup the interradial areas are decidedly impressed causing a splay-toothed appearance, which is rather common for the genus.

Outer ligamental areas of RR are prominent and the muscle areas are well defined. The entire outer surface of the dorsal cup is covered by fine granules. The columnar scar is mildly pentagonal in outline. The arms are not known.

Remarks.—This species is readily distinguishable from other described species because of its unusually large upflared IBB disk. The granular ornamentation is also characteristic of the species.

Occurrence.—The hill, or mound, just west of the city limits of Bartlesville, Oklahoma; Wann formation, Ochelata group, Missourian, Pennsylvanian.

Type.—Collected by H. L. Strimple. To be deposited in the U. S. National Museum.

PLUMMERICRINUS sp.
Plate 23, figures 3–5

This form was found at the hill, or mound, just west of the city limits of Bartlesville, Oklahoma, and is not considered complete enough to warrant description at this time. Surface sculpture consists of fine ridges. The separation of radial articulating facets is not pronounced. The base of the cup is mildly concave and the proximal columnal appears to have an elliptical outline. These characteristics serve to distinguish the form from the associated *P. erectus* and *P. granulosus*.

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JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 208–209, 5 TEXT FIGS., MARCH 1954

A NEW GRAPTOLITE FROM SOUTH DAKOTA

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ABSTRACT—A new species of *Dictyonema* from the Mississippian Englewood formation near Deadwood, South Dakota, is illustrated and described. It is the fourth species of that genus from that locality. It differs from the typical *Dictyonema* in having a more shrub-like appearance with main stipe curved, and with large irregular meshes, or interspaces, plus asymmetrical branching.

INTRODUCTION

A NEW species of graptolite was collected during the summer of 1952 by Robert Hansman from six feet above the base of the Englewood formation, northeast of the outskirts of Deadwood, South Dakota, on the west side of U. S. Highway 85 in the SW ¼, Sec. 13, T. 5 N., R. 3 E., 200 yards north of the junction of U. S. Highways 14 and 85.

The graptolite is a beautifully branched, almost complete colony occurring on the surface of the fine-grained, somewhat dolomitic Englewood limestone. Although the Englewood is a pink slabby limestone, the thin piece on which the graptolite occurs is gray in color, possibly the result of weathering. The light brownish color of the graptolite may be due to staining from the pink limestone. A more recently available fragment of the reverse of the holotype shows some small darker brown fragments of the outer periderm preserved near the ends of a few branches, whereas this outer covering has been completely removed from all the rest of the colony.

Earlier Ruedemann (1947, pp. 193, 194, pl. 13, figs. 6–7, 10–13, 14–15 and 8–9) described and illustrated three species from the Englewood formation, *Dictyonema dakotense*, *D. lochmannae* and *D. mississippiense*, all exhibiting the common, widening, *Dictyonema*-type of colony with narrow, nearly parallel branches; and a somewhat coarser colony, *D. blairi*, from the Mississippian Chouteau limestone, Sedalia, Missouri.

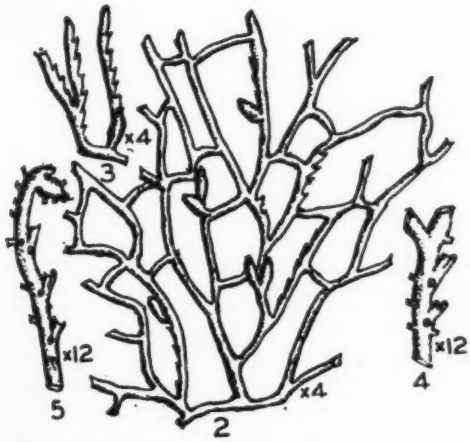
DESCRIPTION OF SPECIES

DICTYONEMA ASPIDOIDES Decker, n. sp.
Figures 1–5

The trivial name *aspidoides* is given because the new colony resembles in a general way Bulman's (1934, pt. III, pp. 71–74, pls. 9, 10) two Lower Ordovician species from England and Wales, *Aspidograptus implicatus* and *A. minor*. However, it differs from these two species in having dissepiments to help enclose meshes, or interspaces, between the branches. Also, it has large swollen structures along the stipes in the form of gonothecae.

FIG. 1—Photograph of colony showing curvature of main stipe, asymmetrical branching, large meshes, or interspaces, and swollen gonothecae along the stipes. ×2.

The shrub-like colony is 21 mm. high and 29 mm. wide. It branches profusely at intervals of about 2 mm. The widest branch has a width of about .5 mm. and it curves as do those in the two species of *Aspidograptus* mentioned above, and like them it has most of the branches on one side. Thecae are indistinct over most of the colony, but in a few places as many as 16 are present in a distance of 10 mm. Bithecae show as circular openings at intervals along the stipes. Large gonothecae are common, and on higher mag-



FIGS. *2–5—2*, photograph of drawing from central part of the colony showing some large interspaces, some thecae, and six gonotheca, ×4; *3*, upper edge of the colony showing thecae and one gonotheca, ×4; *4*, part of a stipe showing two thecae, round apertures of two bithecae, and five tiny nematothecae, ×12; *5*, part of stipe from left edge of colony showing three thecae, apertures of three bithecae, a gonotheca at the upper end, and a number of tiny nematothecae, ×12.

nification, numerous tiny structures occur along the stipes. Some of them are related to gonothecae and thecae, and some of them seem to be in the apertures of the thecae. These are thought to have housed stinging cells, and so are called nematothecae. Possibly the microthecae on *Tubidendron bulmani* shown by Kozlowski (1948, p. 161, text fig. 47 m_7; pl. 19, fig. 1m; pl. 21, fig. 1 m_7) may represent structures with the same function as nematothecae. Nematothecae were found by the writer (1945, p. 29, pl. 9, figs. 2a, 2b) around the apertures of gonothecae on a Cambrian graptolite near Mason, Texas.

Occurrence.—As noted above the graptolite came from the Mississippian Englewood formation at the northeast edge of Deadwood, South Dakota.

Repository.—The holotype will be placed in the Museum of Paleontology, University of Iowa, Iowa City, Iowa.

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JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 210–213, 1 TEXT FIG., MARCH 1954

PALEONTOLOGICAL NOTE

NOTES ON FORAMINIFERA FROM THE LATE CENOZOIC IN SOUTHERN FLORIDA[1]

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J. A. CUSHMAN in 1942 and 1943 prepared checklists of the Foraminifera from samples of certain wells drilled in the subsurface formations of late Cenozoic age in southern Florida. The authors have made detailed examinations of material from the formations in Lee and Charlotte counties, and superficial examinations of material from other places in southern Florida. Figure 1 shows the general location of wells ranging in depth from 20 feet to several hundred feet which were used in the preparation of this paper. Stratigraphic changes in southern Florida resulting from the study of new surface macrofossil collections made it desirable to evaluate the large number of foraminiferal checklists, most of which were prepared by Cushman.

Parker and Cooke (1944) and Cooke (1945) presented the late Cenozoic stratigraphy of southern Florida and subsequently Parker (1951, pp. 821–823) and Hoy and Schroeder (1952, pp. 283–286) introduced the changes made necessary by later work. The generalized stratigraphic sequence is given in table 1.

The authors have made no attempt to review all the literature pertaining to the occurrence of Foraminifera of late Cenozoic age but have restricted themselves to occurrences reported from Florida. The studies by Julia A. Gardner, F. Stearns MacNeil, and Horace G. Richards of macrofossil collections from wells provided a comparative analysis and aided in the identification of some of the formations. Only described species of Foraminifera were utilized for comparison with the published lists of Cole (1931), Cushman and Ponton (1932), and Vernon (1942). The result of this comparison is given by Schroeder and Bishop (1953)

TABLE 1—GENERALIZED SUMMARY OF FORMATIONS OF LATE CENOZOIC AGE IN SOUTHERN FLORIDA*

Formation	Geologic Age	Approximate occurrence in feet below land surface				Character
		Fort Myers area	Caloosahatchee River area	Lake Okeechobee area	Miami area	
Organic soils	Recent	Absent	Commonly absent	0–8	Absent	Peat and muck
Lake Flirt marl	Recent and late Pleistocene	Absent	0–1	Interbedded with organic soils	Absent	Fresh-water marl
Pamlico sand	Pleistocene	0–2	1–2	Absent	0–1	Quartz sand
Miami oolite	Pleistocene	Absent	Absent	Absent	1–40	Soft oolitic limestone
Key Largo limestone	Pleistocene	Absent	Absent	Absent	Interfingers with Fort Thomspon	Coralline limestone
Anastasia formation	Pleistocene	2–5	Absent	Absent	Absent	Sand, limestone, and shell beds
Fort Thompson formation	Pleistocene	Absent	2–7	8–30	40–120	Marine and fresh-water sands, marls, limestone, and shell beds
Caloosahatchee marl	Pliocene	Commonly absent	7–20	30–50	Commonly absent	Shelly sands and shell beds
Tamiami formation	Late Miocene	5–45	20–120	50–180	120–220	Marly sands, marl, and shell beds
Hawthorn formation	Early and middle Miocene	45–600	120–500 ±	180–680	220–850 ±	Clayey and sandy marl

* Some of the formations of Pleistocene age are contemporaneous in part.

[1] Publication authorized by the Director, United States Geological Survey.

TABLE 2—CHECKLIST OF SELECTED FORAMINIFERA FROM THE DEPOSITS OF LATE CENOZOIC AGE

Foraminifera	Pleistocene deposits	Caloosa-hatchee marl	Tamiami formation	Hawthorn formation
Archaias angulatus (Fichtel and Moll)	X	X		
Rotalia caloosahatcheensis Cole	X	X		
Planorbulina mediterranensis d'Orbigny	X	X		
Quinqueloculina agglutinans d'Orbigny	X	X	X	
Quinqueloculina poeyana d'Orbigny	X	X	X	
Triloculina bicarinata d'Orbigny	X	X	X	
Triloculina linnea d'Orbigny var. *caloosa-hatcheensis* Cole	X	X	X	
Bolivina rhomboidalis (Millett)	X	X	X	
Loxostomum mayori (Cushman)	X	X	X	
Rotalia beccarii (Linné)	X	X	X	
Miliammina fusca (H. B. Brady)	X	X	X	R
Nodobacularia antillarum (Cushman)		R		
Triloculina terquemiana (H. B. Brady)		R		
Triloculina tricarinata (d'Orbigny)		R		
Nonionella pseudo-auris Cole		R		
Sorites marginalis (Lamarck)		R		
Uvigerina peregrina var. *bradyana* Cushman		R		
Spirillina limbata H. B. Brady		R		
Discorbis subrugosa Cushman		R		
Amphistegina gibbosa d'Orbigny		R		
Cassidulinoides brazilensis (Cushman)		R		
Globigerina triloba Reuss		R		
Orbulina universa d'Orbigny		R		
Textularia floridana Cushman		R	X	X
Quinqueloculina costata d'Orbigny		R	X	X
Triloculina oblonga (Montagu)		R	X	X
Triloculina trigonula (Lamarck)		R	X	X
Flintia robusta (H. B. Brady)		R	X	X
Nonion glabrellum Cushman		R	X	X
Cassidulina laevigata var. *carinata* Cushman		R		X
Robulus americanus (Cushman)			X	X
Robulus americanus spinosus (Cushman)			R	X
Robulus vaughani (Cushman)			X	X
Marginulina glabra d'Orbigny			X	X
Dentalina communis d'Orbigny			X	X
Nodosaria catesbyi d'Orbigny			X	X
Pseudopolymorphina dumblei (Cushman and Applin)			X	X
Buliminella curta Cushman			X	X
Bulimina elongata d'Orbigny			X	X
Eponides antillarum (d'Orbigny)			X	X
Eponides mansfieldi Cushman			X	X
Candorbulina universa Jedlitschka			X	X
Dyocibicides biserialis Cushman and Valentine			X	X
Valvulineria floridana Cushman				X
Bolivina marginata multicostata Cushman				X
Elphidium chipolensis (Cushman)				R
Cassidulina chipolensis Cushman and Ponton				R
Bulimina elongata d'Orbigny var. (?) spinose base				X

and is presented in tabular form in table 2.

The species indicated by "R" as occurring rarely in the Pliocene occur so infrequently that they are of little aid in differentiating the Caloosahatchee marl from the Pleistocene formations when a large number of samples are to be examined. *Archaias angulatus*, *Rotalia caloosahatcheensis*, and *Planorbulina mediterranensis*, which are found in both the Pleistocene and the Plio-

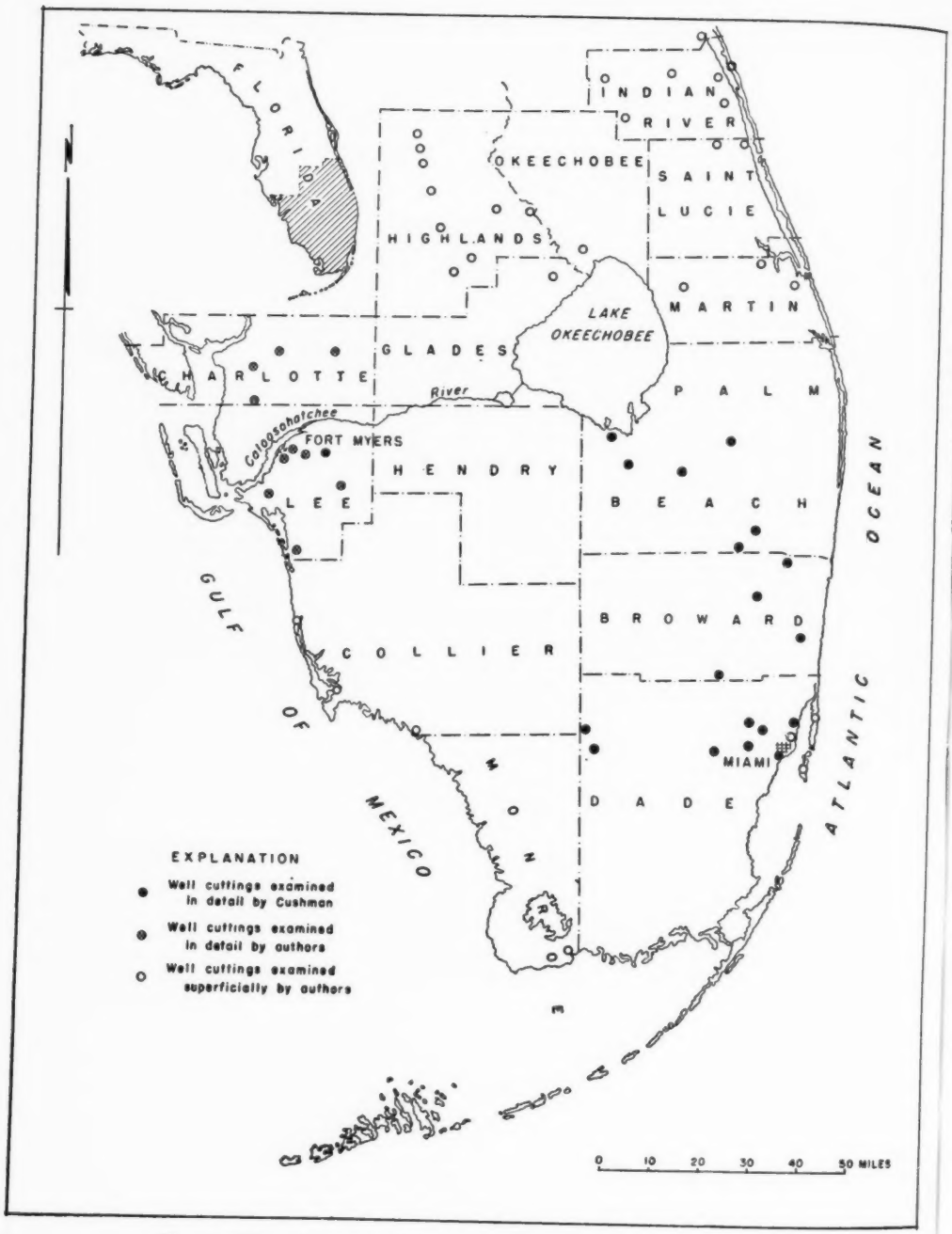

FIG. *1*—Map of southern Florida showing location of selected wells studied for this report.

cene, occur in sufficient abundance to be useful in differentiating the Pleistocene and Pliocene from the Miocene. The Pliocene and Pleistocene are best differentiated with molluscan faunas.

The Tamiami formation contains a fauna composed of a group of species common in the younger sediments and a group which is not found in beds younger than Miocene. This overlapping of groups comprises a characteristic and diagnostic fauna for the Tamiami formation. *Bulimina elongata* which occurs world-wide from the Eocene to Recent was previously described by Cushman and Ponton (1932, pp. 76–77) in Florida as *B. gracilis* Cushman, a name still used for the species by most of the workers in the state. *B. gracilis* has not been found in Florida formations younger than the Miocene nor have specimens of that species having a spinose base been found in sedimentary rocks younger than the Hawthorn.

The differentiation of the upper Miocene deposits from the older Hawthorn formation and the younger Pliocene and Pleistocene formations can be done by means of the faunal groupings listed in this note. It is hoped that the note will be an aid to paleontologic identification of formations of the late Cenzoic age and that it will stimulate investigation and description of the complex foraminiferal faunas of the late Cenozoic of Florida.

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JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 214–218, MARCH 1954

NOMENCLATURAL NOTES

GENOTYPE OF THE OSTRACOD *MOOREA*

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Ostracod literature has become very voluminous, and probably no one has access to all papers which have been published. Frequently the original description of a genus is not accessible, though later observations in regard to it are. If these observations are inaccurate, or are in clear error, the inaccuracies and errors may be, and in many cases are perpetuated for years. An illustration of this is the genus *Moorea*.

The Bassler and Kellett "Index" (1934, p. 413) gives the following synonymy of the genus:

MOOREA Jones and Kirkby (Youngiellidae)

Genotype: *M. obesa* Jones

Moorea JONES and KIRKBY, Geol. Soc. London, Quart. Jour., 23 (1867) p. 494—JONES and HOLL, Ann. Mag. Nat. Hist., ser. 4, 3 (1869) p. 225—JONES, Monthly Micr. Jour., 4 (1870) p. 193—NICHOLSON and LYDEKKER, Man. Pal., 1 (1879) p. 506—JONES and KIRKBY, Geol. Assoc. London, Pr., 9 (1886) p. 508; Ann. Mag. Nat. Hist., ser. 5, 19 (1887) p. 409—VOGDES, New York Acad. Sci., Ann., 5 (1889) p. 4—MILLER, North American geol. pal., appendix (1892) p. 709—ULRICH, Geol. Minn., 3, pt. 2 (1894) p. 681—GRABAU, Buffalo Soc. Nat. Sci., Bull., 6 (1899) p. 309—ULRICH and BASSLER, U. S. Nat. Mus., Pr., 30 (1906) p. 155—GRABAU and SHIMER, North American index fossils (1910) p. 350—BASSLER, U. S. Nat. Mus., Bull. 92 (1915) p. 838—ULRICH and BASSLER, Md. Geol. Surv., Silurian vol. (1923) p. 215, 316—ROTH, Wagner Free Inst. Sci., Publ., 1 (1929) p. 8.

The first difficulty one encounters when examining the literature is that page 494 of the Geological Society of London's Quarterly Journal is not by Jones and Kirkby as indicated above, but in a portion of a paper by Moore, which contains a list of "Organic Remains," one of which is given as "*Moorea tenuis* Jones, MS." The name "Moorea obtusa Jones" appears at the top of page 523 of Moore's article, which Jones and Holl (1869, p. 226) indicate was a misprint and was intended to be *Moorea obesa*. The name "*Moorea obesa* Jones, MS." appears in another list of "Organic Remains" at the top of page 525, and again with *Moorea tenuis* in a table on page 559 of Moore's article. In no place does Moore refer these species to "Jones and Kirkby," but rather to Jones. None of them are accompanied by descriptions or pictures, and they must therefore be considered as nude names.

As far as I have been able to ascertain, Jones and Holl (1869, pp. 225–226) give the first description of the genus as follows:

MOOREA, Jones & Kirkby, MS.

During an examination some time since of a series of bivalved Entomostraca collected by Mr. Charles Moore, F.G.S., from the contents of some fissures in the Carboniferous Limestone of Somersetshire and elsewhere, Messrs. Jones & Kirkby discriminated a few specimens having simple, thick, flattened carapace-valves, longer on the dorsal than the ventral margin, without any subcentral pit, and ornamented with narrow, rounded ridges, following more or less closely and completely the marginal contour. Some *Kirkbyæ* are but

slightly convex, and bear superficial ridges, both circular and longitudinal (such as *Kirkbya fibula*, fig. 9, and *K. costata*, M'Coy, sp.); but all have some trace of a subcentral pit or notch, and the group is therefore distinct. These new forms were referred to in the Quart. Journ. Geol. Soc. vol. xxiii. (1867) pp. 494, 523, and 559, as *Moorea obesa* and *M. tenuis*, Jones, MS. (once with a misprint of *obtusa* for *obesa*). We have now to notice another and still older * species of this ancient family of Entomostraca, the members of which seem (as far as the carapace is concerned) to present closely related genera, linking together *Leperditia*, *Primitia*, *Beyrichia*, *Kirkbya*, and *Moorea* by various gradations and resemblances in the structure of the valves. Knowing that existing Entomostraca, with mutually similar carapaces differ among themselves as to essential limb-characters, we feel more and more inclined to lay stress on differences in the features of the fossil valves, and to keep distinct all well-marked forms remaining from among the almost lost tribes of these little primæval Crustacea.

* I do not fall in with Mr. Charles Moore's belief that the Entomostraca above referred to are of Liassic age, and were deposited in the fissures from the sea of that period, but rather believe them to have been derived by degradation from the fissured limestone.—T. R. J.

This generic description by Jones and Holl was followed on pages 226–227 by the single description of the following species, and it is reproduced below:

Moorea silurica, sp. nov. Pl. XV. figs. 8 *a*, 8 *b*.

Carapace-valves subovate, one-third longer than high, slightly convex, polished, but coarsely punctate, and bearing a raised marginal rim. Dorsal edge straight; dorsal corners rounded. Ventral border presenting a nearly true segment of a circle. Ends somewhat obliquely rounded, nearly equal in outline. A stout elevated ridge runs along nearly the whole margin of the valve. It may be said to begin on the hinder edge, which is depressed, but strongly lipped by the marginal rim standing out sharply backwards; it thickens on the ventral border, is very thin anteriorly, and rises high along the dorsal region, until it turns suddenly downwards, to lose itself in the general surface of the posterior third of the valve.

In some individuals the raised rim above the ventral border is but faintly marked; in others the marginal rim is strongly developed, both above and below, and almost meets behind.

Only single valves have been met with; but in its ventral aspect the carapace was probably somewhat like a compressed orange-pip, partly split at one end. The greatest convexity is about the centre of the valves.

The ventral border of the figured valve (fig. 8 *b*, probably the right and overlapping valve) is flattened suddenly by the projection of the marginal rim, and by being turned inwards for a considerable depth. Its extreme edge has for most of its length a delicate raised rim, which, however, passes outwards and backwards to join the great marginal ridge, where the latter projects as a thick, sharp-edged crest along the posterior edge of the valve. Somewhat analogous features may be traced in *Primitia cristata*, J. & H., Ann. Nat. Hist. ser. 3. vol. xvi. pl. 13. fig. 1.

The dorsal border of *Moorea silurica* is indented along its marginal ridge, so as to form with its fellow, if similarly constructed, a narrow elliptical depression at the back, along the hinge-line, as in *P. cristata* above alluded to.

Our specimens were found in a band of micaceous limestone in the Upper Ludlow rocks, with *Kirkbya fibula*, at Hales End, Malvern, where it was not uncommon.

Bassler and Kellett (1934, p. 414) give this synonymy for *Moorea obesa*, the species they consider to be the genotype:

Moorea obesa Jones and Kirkby — Carboniferous

Moorea obesa Moore, Geol. Soc. London, Quart. Jour., 23 (1867) p. 525, 559—Jones and Holl, (misprint, *obtusa*) Ann. Mag. Nat. Hist., ser. 4, 3 (1869) p. 226—Jones and Kirkby, Ann. Mag. Nat. Hist., ser. 5, 18 (1886) p. 261, pl. 8, figs. 20a, b; Geol. Soc. London, Quart. Jour., 42 (1886) p. 496, 512—Ulrich and Bassler, Md. Geol. Surv., Silurian vol. (1923) p. 315, text fig. 22 (fig. 3).

Limestone: Glamorganshire, England.

As far as I have been able to ascertain, *Moorea obesa*, while twice listed by Moore (1867, pp. 525, 559) and attributed by him to Jones, was for the first time described by Jones and Kirkby (1866, p. 261, pl. 8, figs. 20a, b). Jones and Kirkby (1886) indicate in their description that they were then describing the species as new, and the description is reproduced below:

29. *Moorea obesa*, sp. nov.
(Pl. VIII. figs. 20 *a*, 20 *b*.)

Subtriangular in outline, greatest length rather below the dorsal border; dorsal border incurved; ventral and extreme borders forming an inverted arch; extremities pointed; free margins rimmed, a little inside of which is another and stronger ridge, continuous and concentric; main area of valve smooth. Length $\frac{1}{10}$ inch.

A very rare species, and only known from the *débris* of Carboniferous Limestone in a vein at Brocastle, near Bridgend, Glamorganshire, where it was collected by Mr. Charles Moore, F.G.S.

The above erroneous references in Bassler and Kellett appear to have caused Warthin (1948, *this Journal*, p. 646) to write the following:

Genus Moorea Jones and Kirby 1867

Miller (1892, p. 709) cites *M. silurica* Jones and Holl as genotype, but since *silurica* was not described until 1869, and is not in the original list of species ascribed to this genus, this designation is invalid, and that of *M. obesa*, used in the Bassler-Kellett index, (1934, p. 413) is correct.

In this same paper Warthin had pointed out the correctness of Miller's designation of the type species of the genera *Primitia*, *Bollia*, and *Halliella*, and had pointed out that the Bassler and Kellett index was in error. In this case, however, Warthin must not have had access to Moore's (1867) paper. It must be pointed out that the genus *Moorea* was not described in this paper, and the only species of *Moorea* listed are attributed to Jones, not Jones and Kirkby. The species mentioned are not given in a single list, and appear in this order: *M. tenuis* Jones, M.S., *M. obtusa* Jones, and then *M. obesa* Jones, M.S. If Warthin's reasoning be valid that this original listing of manuscript names "ascribed to the genus" be adhered to, then both the genus and species should be attributed to Jones, rather to Jones and Kirkby.

Fortunately, Opinion 97 of the International Committee on Zoological Nomenclature covers the above point, and the critical point of this opinion is quoted:

"Even if it be admitted that the binomials represent combinations of generic plus specific names, they are essentially *nomina nuda* (as of the date in question) since authors who do not possess esoteric information in regard to them are unable definitely to interpret them without reference to later literature. If published with more definite data at later dates, these names have their status in regard to availability as of their date of such republication."

The effective date for *Moorea obesa* is then 1886, and the species should be attributed to Jones and Kirkby, rather than to Jones as it was originally given.

Henningsmoen (1953, pp. 246, 273) has apparently followed Warthin in his "Classification of Paleozoic Straight-Hinged Ostra-

cods," as he gives the date of *Moorea* Jones and Kirkby as 1867, when it should be 1869.

In summary *Moorea silurica* Jones and Holl 1869, must be the type species of *Moorea* Jones and Kirkby, MS, Jones and Holl 1869, by *monotypy* under Article 30c of the International Rules. It would appear that this is fortunate from a reading of the description of each species; *M. obesa* being rare and from a questionable locality. I make no pretense of being an authority on Paleozoic ostracods, and have merely pointed out what has been found from an examination of the literature. The two species, however, look quite dissimilar in their illustrations, and I feel that it is important to point out that the type *Moorea silurica* Jones and Holl was described from the Silurian, rather than from the Carboniferous. If someone familiar with the genus actually examines these species, it is possible that they will be found to belong to different genera.

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STENZELIA, NEW NAME FOR *TRINACRIELLA* MACNEIL

F. STEARNS MACNEIL

U. S. Geological Survey, Washington 25, D. C.

Trinacriella MacNeil 1937 (Washington Acad. Sci. Jour., vol. 27, no. 11, p. 456) was proposed as a subgenus of *Halonanus* Stewart. Both were referred to the Trinacriinae, a subfamily (of Noetidae) of prionodontid mollusks. According to Neave (Nomenclator Zoologicus, vol. 4, 1940) the name is twice preoccupied. *Trinacriella* MacNeil was not listed by Neave in either the original Nomenclator or in the supplements and addenda.

The following new name is proposed:

Stenzelia MacNeil (new name for *Trinacriella* MacNeil 1937, not Del-Guerico 1913 or Parona 1933). Type (of *Trinacriella*): *Pectunculus perplanus* Conrad.

According to H. B. Stenzel (written communication), *Halonanus* Stewart may be a synonym of *Pachecoa* Harris. In that event, *Stenzelia* is properly a subgenus of *Pachecoa*.

VENTRICOLARIA AND *SIMILIVENUS INSOLIDA*, NEW NAMES IN THE PELECYPOD FAMILY VENERIDAE

A. MYRA KEEN

Stanford University, California

Ventricola Römer, 1867 (Malak. Blätter 14, p. 115) was proposed for a number of species previously assigned to *Venus*, without indication of type. Dall in 1902 (Proc. U. S. Nat. Mus. 26, p. 355) cited *Venus rugosa* Gmelin, 1790 (not Linné, 1767 [= *V. rigida* Dillwyn, 1817]), a designation that has been accepted by most authors. Unfortunately, there is an earlier type designation by Kobelt, 1881 (Illustrirtes Conchylienbuch, vol. 2, p. 338). Unless a yet earlier and different one can be found—which seems unlikely—Kobelt's selection of *Venus verrucosa* Linné, 1758, makes *Ventricola* an

absolute synonym of *Venus* Linné, 1758. As the *Ventricola* of authors comprises a well-knit and distinctive group of late Tertiary and Recent species worthy of generic or subgeneric recognition, I propose as a replacement the slightly altered name *Ventricolaria* Keen, new name, with *Venus rigida* Dillwyn, a Recent Caribbean species, as type.

Cossmann in 1910 (Act. Linn. Soc. Bordeaux 64, p. 333) founded *Similivenus* as a "section" of *Marcia:* type, by original designation, *Venus solida* Deshayes, 1825, a species from the Eocene of the Paris Basin. This specific name is preoccupied by *Venus solida* Schroeter, 1802, validly proposed for a Recent form of unknown provenance; hence, Deshayes' name must be rejected as a primary homonym however unrecognizable Schroeter's species may be. A search of literature reveals no synonym or subspecific name that could be used in substitution. With reluctance, then, I suggest that the long-established *Venus solida* Deshayes be replaced by *Similivenus insolida* Keen, new name. The type material of *Venus solida* comprises several lots in the Deshayes collection, housed in the École des Mines, Paris. No holotype seems to have been segregated. I therefore designate as holotype of the renamed species the specimen figured by Deshayes (Descr. coq. env. Paris, vol. 1, p. 144, pl. 25, figs, 3–4). As suggested by M. Max Desjardins (personal communication, Oct. 12, 1953), who has kindly examined the material for me, this is probably one of six separated valves in a bottle of material from Acy (Oise), Deshayes' first-cited locality, which he recorded as "Assy-en-Mulitien."

NOMENCLATURE OF FAMILIES AND SUPERFAMILIES

W. J. ARKELL
Sedgwick Museum, Cambridge, England

May I draw attention to clause 54(1)(a) of the "Additions to, and modifications of, the Règles Internationales de la Nomenclature Zoologique approved and adopted by the XIVth International Congress of Zoology, Copenhagen, August 1953?" This clause directs that where the name of the type genus of a subfamily, family, or superfamily has been changed because it is a junior synonym (whether objective or subjective), the name of the subfamily, family, or superfamily based upon the name of that type genus is not to be changed.

Our colleagues who sacrificed their time, energies and funds in attending the Copenhagen Congress achieved so much that is excellent and put us so greatly in their debt, that it seems ungracious to criticize their decisions. On this particular point, however, there surely must have been sharp division of opinion. The decision would have such unhappy effects in at least molluscan systematics that, if Mollusca are a fair sample, I feel paleontologists should do all possible to prevent this clause from being incorporated in the new Rules of Nomenclature.

Some of the changes that would be required would produce completely unfamiliar monstrosities, for some family names formed on invalid objective synonyms have been jettisoned and ignored almost from the moment of proposal, along with the invalid nominal genus. The prospect of family and superfamily names henceforth having to be altered so as to revive and immortalise invalid junior synonyms is as daunting as the prospect of the discreditable hunt that may be started among the literature, to be the first to unearth these corpses for revival.

If all paleontologists who object to this clause becoming part of the Rules will write to the Secretary of the International Commission on Zoological Nomenclature, Mr. Francis Hemming, 28 Park Village East, Regents Park, London W. 1, let us hope that our protests may avail. If any systematist feels that in an exceptional case it is desirable to retain a well-known family name based on an invalid synonym, it is always open to him to apply for the protection of the Commission on behalf of that name. Otherwise, the Rules surely should state the obvious: namely, that the legitimate name of a family (or subfamily or superfamily) is that which is formed on the valid name of the type genus.

This note is being sent to the Geological Magazine (London) in form of a letter, and copied to Mr. Francis Hemming.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 219–222, MARCH 1954

NOTICES

ADVISORY COMMITTEE ON RADIOACTIVE MINERAL EXPLORATION

In July, 1952, a notice was published in the JOURNAL OF PALEONTOLOGY announcing the organization of a committee to be known as the "Advisory Committee on Radioactive Mineral Exploration." This committee is jointly sponsored by the A.A.P.G., S.E.G., and S.E.P.M., and is composed of delegates appointed by the presidents of the societies named. This committee serves only in an advisory capacity and its primary functions are:

a. To invite those who may be inclined or interested, to investigate the feasibility of their carrying on exploration for radioactive minerals along with their petroleum exploratory efforts;

b. To give advice as to how and where such exploration for radioactive minerals may be conducted, if desired;

c. To advise where information can be obtained concerning the search for radioactive materials;

d. To endeavor to keep abreast of what is going on in this search for radioactive materials; and

e. To encourage the preparation and presentation of papers on the subject of exploring for useful radioactive minerals.

This committee will concern itself with over-all encouragement of participation of the oil and gas industry in exploration for radioactive minerals and will deal with the broad aspects and policies of such a relationship. It will not be too much concerned with detailed techniques, problems of instrumentation, methods, and processes for detailed surveys, nor with any of the technical aspects of the program which may better be handled by specialists. In no way will it suggest unified cooperation, or cooperative procedure, between organizations for the conduct of radioactive mineral exploration. Its whole objective is to stimulate an interest in the search for radioactive minerals, occurring within feasible mining depths, when and where petroleum exploration is in progress.

A statement drawn up by the committee at the 1952 meeting in Denver, and published along with the notice of organization in the July 1952 issue of the JOURNAL OF PALEONTOLOGY, has since been set up in mimeographed form by the committee as Circular 1, and has been followed by Circulars 2, 3, and 4. Those who are interested in obtaining copies of these circulars should write to the chairman. The committee will endeavor to answer any questions within the scope of its functions, or to direct the inquirer to a suitable source of information. Communications may be addressed to the chairman.

In the following list of members of the committee, S.E.P.M. members are indicated. The appointed delegate for the S.E.P.M. is Mr. Clifford C. Church.

Frederic H. Lahee, Chairman
(Box 2880, Dallas, Texas)
Henry C. Cortes, Vice-Chairman
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INTERNATIONAL SCHOLARS FORUM

As all scholars to their sorrow know, high manufacturing costs in the publishing field make it increasingly difficult to place manuscripts likely to have a limited sale. Big commercial houses are more and more unwilling to risk financial loss. University presses, which were once the recourse of the scholar, find it necessary to ask for large subventions and guarantees. The INTERNATIONAL SCHOLARS FORUM has been organized in the belief that many first-rate manuscripts are circulating in vain search of a publisher.

The underlying idea of this series is simply the recognition that publishing costs are much lower on the European continent than in this country. Unfortunately, American authors do not know much about European publishers, and these publishers, for their part, find it difficult to evaluate the American manuscripts submitted to them. The Advisory Board of the INTERNATIONAL SCHOLARS FORUM has therefore entered into an agreement with Martinus Nijhoff of The Hague to receive manuscripts, appraise them, and make recommendations regarding publication. While the publisher reserves the right of final decision, it is thought that this arrangement will both facilitate the flow of manuscripts and assure other authors in the Series of the substantial quality of companion volumes.

Where an American publisher requires an edition of 2,000 or more copies to break even, Mr. Nijhoff is prepared to publish an edition of as few as 500 copies. Authors who, on a realistic assessment of their sales potential, conclude that it will be limited chiefly to libraries and to other scholars in the field, should therefore consider the possibility of submitting their manuscripts for publication in the INTERNATIONAL SCHOLARS FORUM. In addition to extensive European outlets, Mr. Nijhoff has an American outlet. Moreover he regularly circulates catalogues and announcements of publication in this country. With review copies sent to learned journals, an author should therefore have as large an audience as he could expect with an American publisher, and he would have a substantially larger European audience.

Authors will enter into individual contracts with the publisher. Mr. Nijhoff believes that it will frequently be possible for him to publish without any subvention; where a subvention is asked, it will be considerably less than the guarantee required by an American publisher. Authors who submit manuscripts should understand that European publishing practices differ somewhat from those in this country. While authors are expected to do the main job of proof reading, the publisher is extremely generous about submitting proof, even in the page stage. Costs of correction are borne by the publisher, as far as printing errors in the first and second proof are concerned; authors are charged for the cost of author's correction only. In short, an author who is prepared to take pains on his manuscript as well as on his first and second proof will find the arrangements entirely satisfactory. The finished product will be of high quality, as Mr. Nijhoff has a reputation throughout Europe and the U.S.A. for the appearance of his books.

FOR FURTHER INFORMATION APPLY TO THE LIBRARIAN OF THE HONNOLD LIBRARY CLAREMONT, CALIFORNIA

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SCIENTIFIC MANPOWER COMMISSION

1530 P Street, N. W., Washington 5, D. C.

HISTORY

In 1950 Korea set off a chain of events that focused the attention of scientific and engineering organizations on manpower problems, none of which had been satisfactorily solved in World War II. Military requirements for personnel, full employment, accelerated industrial production, and college enrollments that fell short of the demand for professionally trained men and women created a complex situation that could best be analyzed and resolved by a single agency representing all the scientific disciplines. To meet this need eight major professional groups established the Scientific Manpower Commission in March 1953, to serve the societies, their affiliates, and their 130,000 members, and also to serve the employers of scientists and the people of a nation that has a very large stake in continuing scientific development. The Commission's constitution invites participation by other organizations that are concerned with specialized manpower.

ACTIVITIES

There is no clearly defined national policy relative to scientific personnel. In the conviction that the facts of the situation will furnish the soundest guide to action, the Commission has devoted its first seven months of life to fact-finding and analysis. It has completed a survey of career guidance literature, and in the field of recruitment it is working with The Future Scientists of America Foundation and with the International Committee on Vocational Guidance of Kiwanis International. It has analyzed available studies and statistics dealing with the supply of scientists and is investigating trends and variables that may affect supply. A Commission panel is currently preparing estimates of demand for scientists in each major field, in an effort to provide basic information that will guide industry, education, and government in the formulation of policy. A special study of the utilization of scientists in institutions of higher learning is also in progress.

Cooperation with other organizations and agencies has extended the Commission's activities in many directions. It has worked with the Engineering Manpower Commission in support of sound reservist legislation, and it is represented at meetings of EMC and the EMC Executive Committee. By invitation, a representative attends all meetings of the Office of Defense Mobilization Committee on Specialized Personnel. It has functioned as unofficial consultant on scientific classifications to the government committee responsible for the Lists of Critical Occupations and Essential Activities. It has collaborated with the National Science Foundation and National Research Council in arranging symposia on manpower problems at home and abroad, presented at the Boston meeting of the American Association for the Advancement of Science (December 28–29).

1954

Other agencies, both public and private, are engaged in manpower studies, but many aspects of the problem are being neglected, and no other group seems sufficiently concerned about the field as a whole or about the integration of isolated activities into a coordinated and coherent program. Although the Scientific Manpower Commission must necessarily confine itself to projects that lie within the compass of its modest budget and small staff, its primary aim will be to function as a catalyzer and to coordinate activities to the end that recruitment, training, and utilization of scientists will be seen as an integrated sequence of responsibilities with which the professional societies, industry, education, government, and the public are all vitally concerned. The specific projects that will receive the Commission's attention will be designed to advance this major objective.

MEMBERS OF THE SCIENTIFIC MANPOWER COMMISSION

Nominated by American Association for the Advancement of Science:

Wallace R. Brode, National Bureau of Standards

Detlev W. Bronk, Rockefeller Institute for Medical Research

Nominated by American Chemical Society:
M. T. Carpenter, Standard Oil Company of Indiana
B. R. Stanerson, American Chemical Society

Nominated by American Geological Institute:
Benjamin F. Hake, Western Gulf Oil Company
Howard A. Meyerhoff, Scientific Manpower Commission

Nominated by American Institute of Biological Sciences:
Frank P. Cullinan, Bureau of Plant Industry, Soils, and Agricultural Engineering
John S. Nicholas, Yale University

Nominated by American Institute of Physics:
Henry A. Barton, American Institute of Physics
George R. Harrison, Massachusetts Institute of Technology

Nominated by American Psychological Association:
Leonard Carmichael, Smithsonian Institution
Dael Wolfle, Commission on Human Resources and Advanced Training

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Milton O. Lee, Federation of American Societies for Experimental Biology
Joseph H. Roe, George Washington University School of Medicine

Nominated by Policy Committee for Mathematics:
E. G. Begle, Yale University
Stewart S. Cairns, University of Illinois

SCIENTIFIC MANPOWER COMMISSION PROGRAM FOR 1954

In its operations the SCIENTIFIC MANPOWER COMMISSION will cooperate with the Engineering Manpower Commission, but it will assume specific responsibility for:

1. Completion of the Survey of current and future demand for scientific personnel in industry, education, and government.
2. Completion of the survey of utilization of scientists in institutions of higher learning.
3. Cooperation with EMC and other organizations to secure action that will assure appropriate handling of industrial and educational deferments and the recall of reservists.
4. Accumulation, analysis, and distribution of facts and figures on supply and demand for scientists.
5. Cooperation with sponsoring and educational organizations and with industry in the preparation and distribution of career guidance information and in other activities designed to interest students in science and to inform career guidance counselors.
6. Organization of, and participation in, conferences, meetings, and other activities aimed to develop a program of recruiting, training, and utilizing scientific personnel.
7. Dissemination of authentic information on the manpower situation through a joint *EMC-SMC Newsletter*, the press, magazines, radio, and such other media as are available.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 223–248, MARCH 1954

SOCIETY RECORDS AND ACTIVITIES

PROGRAM FOR S.E.P.M., ST. LOUIS MEETING,
H. A. Ireland, Technical Program Chairman

TUESDAY, APRIL 13 — 9:00 to 12:00 A.M.

Opera House, Kiel Auditorium

JOINT SESSION

PRESIDENTIAL ADDRESSES

Presiding for S.E.P.M.—Marcus A. Hanna, Gulf Oil Corporation, Houston, Texas

TUESDAY, APRIL 13 — 2:00 to 5:00 P.M.

Assembly Hall No. 2, Kiel Auditorium

MINERALOGY AND SEDIMENTARY PETROLOGY

Presiding: H. A. Ireland and D. H. Eargle.

1. LOWER PENNSYLVANIAN SEDIMENT SOURCES OF THE EASTERN INTERIOR BASIN (15 mins.)
   Raymond Siever and Paul Potter, Illinois State Geological Survey, Urbana, Ill.
2. FACIES DEVELOPMENT AND INTERTONGUING IN THE BOOK CLIFFS OF EASTERN UTAH (10 mins.)
   Robert G. Young, The California Co., Casper, Wyoming
3. THE PROCESS OF DEPOSITION OF THE SALINA SALT OF MICHIGAN (10 mins.)
   Louis F. Dellwig, University of Kansas, Lawrence, Kan.
4. A COMPARATIVE STUDY OF THE UPPER CHESTER AND LOWER PENNSYLVANIAN STRATIGRAPHIC VARIABILITY (15 min.)
   Paul E. Potter and Raymond Siever, Illinois State Geological Survey, Urbana, Ill.
5. STATISTICAL ANALYSIS OF FACIES PATTERNS (15 mins.)
   W. C. Krumbein, Northwestern University, Evanston, Ill.
6. SEDIMENTATION PHENOMENA IN A MOUNTAINOUS SOURCE AREA (10 mins.)
   Alton F. Wade, Miami University, Oxford, Ohio
7. HYSTRICHOSPHERIDS, A NEW TOOL FOR OIL EXPLORATION (10 mins.)
   L. R. Wilson, University of Massachusetts, Amherst, Mass. and W. S. Hoffmeister, The Carter Oil Co., Tulsa, Okla.
8. SEDIMENTARY CHARACTERISTICS OF PRODUCING ZONES IN WEST BROCK AREA, CARTER COUNTY, OKLAHOMA (15 mins.)
   L. L. Sloss and E. C. Dapples, Northwestern University, Evanston, Ill.
9. PETROLOGY OF SPRINGER OIL BEARING SANDSTONE (10 mins.)
   Lynn Jacobsen, University of Kentucky, Lexington, Ky.
10. THE ORIGIN OF NATIVE SULFUR IN THE GULF COAST SALT DOMES (15 mins.)
    J. Laurence Kulp, Lamont Geological Observatory (Columbia University), Palisades, New York
11. A SIMPLE CORING TUBE FOR SOFT SEDIMENTS (5 mins.)
    Marcus A. Hanna, Gulf Oil Corp., Houston, Texas

WEDNESDAY, APRIL 14 — 9:00 to 12:00 A.M.

Opera House, Kiel Auditorium

JOINT SESSION

Presiding for S.E.P.M.—W. T. Rothwell, Jr., Richfield Oil Corporation, Long Beach, California

1. SIGNIFICANT EXPLORATORY DEVELOPMENTS IN 1953 (20 mins.)
   Philip C. Ingalls, Socony-Vacuum Oil Co., Inc., New York, New York
2. INTRODUCTION TO THE OIL AND GAS GEOLOGY OF THE GREAT PLAINS REGION (20 mins.)
   Theodore A. Link, Link and Nauss Ltd., Toronto, Ontario, and Calgary, Alberta
3. GEOLOGIC FRAMEWORK OF THE GULF COASTAL PLAIN OF TEXAS (20 mins.)
   J. W. Waters, P. W. McFarland, and J. W. Lea, Sun Oil Company, Dallas, and Corpus Christi, Texas

Intermission: 10 minutes

4. THE PRESENT STATE OF GEOTHERMAL INVESTIGATIONS (25 mins.)
Francis Birch, Harvard University, Cambridge, Massachusetts

5. A SEISMIC REFLECTION QUALITY MAP OF NORTH AMERICA (25 mins.)
Paul L. Lyons, Anchor Petroleum Company, Tulsa, Oklahoma

6. THICKNESS MAPS AS CRITERIA FOR REGIONAL STRUCTURAL MOVEMENTS (20 mins.)
Wallace Lee, Kansas Geological Survey, Lawrence, Kansas

7. OIL AND GAS PRODUCTION FROM NON-REEF CARBONATE RESERVOIRS (30 mins.)
Frank B. Conselman, Abilene, Texas

WEDNESDAY, APRIL 14 1:30 to 4:30 P.M.

Assembly Hall No. 2
Kiel Auditorium

FAUNAL FACIES AND THEIR LITHOLOGIC ASSOCIATIONS

Presiding: E. C. Dapples and Heinz Lowenstamm

1. SOME MODERN FAUNAL AND LITHOLOGIC ASSOCIATIONS (25 mins.)
Fred B. Phleger, Scripps Institution of Oceanography, La Jolla, California

2. RELATIONSHIPS OF INVERTEBRATE ORGANISMS IN PENNSYLVANIAN STRATA (25 mins.)
L. M. Cline, University of Wisconsin, Madison, Wisconsin

3. RELATIONSHIP BETWEEN FAUNA AND LITHOLOGY IN THE MOENKOPI FORMATION (25 mins.)
Edwin D. McKee, U. S. Geological Survey, Denver, Colorado

4. A QUANTITATIVE LITHOFACIES AND BIOFACIES STUDY OF THE FLORENA SHALE (PERMIAN) OF KANSAS. (25 mins.)
John Imbrie, Columbia University, New York, New York

5. SAMPLE-POPULATION CONCEPTS IN FAUNAL-LITHOLOGIC FACIES STUDIES (25 mins.)
Robert L. Miller and Everett C. Olson, University of Chicago, Chicago, Illinois

ANNUAL BUSINESS MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(The meeting will be called to order at the termination of the discussion period of the symposium, and possibly could begin prior to 4:30 P.M. Members are urged to be present.)

THURSDAY, APRIL 15 9:00 to 12:00 A.M.

Assembly Hall No. 2
Kiel Auditorium

SYMPOSIUM: REGIONAL ASPECTS OF CARBONATE DEPOSITION

Presiding: Dan Feray and Frank E. Lozo, Jr.

1. THE DISTRIBUTION OF MARINE CARBONATE SEDIMENTS (30 mins.)
John Rodgers, Yale University, New Haven, Connecticut

2. CALCIUM CARBONATE DEPOSITS OF THE GREAT BAHAMA BANK, B. W. I. (30 mins.)
Norman D. Newell and J. Keith Rigby, American Museum of Natural History and Columbia University, New York, New York. (Paper to be presented by Walter H. Bucher, Columbia University, New York, New York.)

3. EARLY DIAGENESIS AND LITHIFICATION OF CARBONATE SEDIMENTS IN SOUTH FLORIDA (30 mins.)
Robert N. Ginsburg, University of Miami-Marine Laboratory, Coral Gables, Florida

4. MISSISSIPPIAN CARBONATE DEPOSITS OF THE OZARK REGION (30 mins.)
Raymond C. Moore, University of Kansas, Lawrence, Kansas

(10 Minute Recess)
Part II: Panel Discussion

Discussion of each paper will be deferred until all papers have been presented. Topics covered by the papers and other phases of the carbonate deposition will be discussed in a special panel session which will be held following the papers. Approximately 45 minutes will be available for the discussion. Panel members will consist of all speakers and co-authors.

THURSDAY, APRIL 15 2:00 to 5:00 P.M.

Assembly Hall No. 2, Kiel Auditorium
GENERAL PALEONTOLOGY

Presiding: F. M. Swain and Allen F. Agnew

1. LITHOLOGIC AND FAUNAL CHARACTERISTICS OF LOWER CRETACEOUS AND PRE-CRETACEOUS LIMESTONE OF SOUTH PENINSULAR FLORIDA (15 mins.)
   P. L. and E. R. Applin, U. S. Geological Survey, Jackson, Mississippi

2. RECENT OSTRACOD BIOFACIES IN EAST MISSISSIPPI DELTA AREA (10 mins.)
   Doris Malkin Curtis, La Jolla, California

3. POST-GLACIAL STRATIGRAPHY ALONG THE CENTRAL TEXAS COAST (20 mins.)
   F. P. Shepard and D. G. Moore, Scripps Institution of Oceanography, La Jolla, California

4. NON-MARINE MICROFAUNA OF FRONTIER FORMATION, COALVILLE, UTAH (15 mins.)
   Daniel J. Jones, University of Utah, Salt Lake City, Utah

5. A CRETACEOUS VERTEBRATE FAUNA OF MINNESOTA AND SOUTH DAKOTA (5 mins.)
   Robert E. Sloan, University of Minnesota, Minneapolis, Minnesota

6. SOME FORAMINIFERA, RADIOLARIA, AND OSTRACODA FROM THE CRETACEOUS OF MINNESOTA (5 mins.)
   Edward J. Bolin, State Geological Survey, Vermillion, South Dakota

7. THE ISOLATION AND CULTIVATION OF MICRO-ORGANISMS FROM DEEP WELL BORINGS IN THE WILLISTON BASIN (15 mins.)
   James M. Williams, Willard D. Pye, Casper I. Nelson, Departments of Geology and Bacteriology, North Dakota, Agricultural College, Fargo, North Dakota

8. DISTRIBUTION OF MARINE UPPER JURASSIC OSTRACODES, WESTERN INTERIOR U. S. (15 mins.)
   James A. Peterson, Shell Oil Company, Salt Lake City, Utah

9. PALEOZOIC FOSSILS IN CRETACEOUS CONGLOMERATES FROM COLORADO (10 mins.)
   John Chronic, University of Colorado, Boulder, Colorado

10. LATE MISSISSIPPIAN-EARLY PENNSYLVANIAN OF SOUTHERN MIDCONTINENT (10 mins.)
    Maxim K. Elias, University of Nebraska, Lincoln, Nebraska

11. LITHOLOGIC FEATURES OF CORES OF JURASSIC LIMESTONE FROM A DEEP WELL IN SOUTH MISSISSIPPI (10 mins.)
    P. L. and E. R. Applin, U. S. Geological Survey, Jackson, Mississippi.

JOURNAL OF PALEONTOLOGY, VOL. 28, NO. 2, PP. 226–248, MARCH 1954

SOCIETY RECORDS AND ACTIVITIES

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Campbell, David G.
Fullerton—
Stevenson, Robert Everett
Gardena—
Terry, Richard D.
Glendale—
Conrey, Bert L.
Hollywood—
Corey, William Henry
Inglewood—
Bettinger, Charles E.
La Canada—
Siegfus, Stanley S.
La Jolla—
Arrhenius, Gustaf O. S.
Bramlette, M. N.
Curray, Joseph R.
Curtis, Doris Malkin
Curtis, Neville Mackay, Jr.
Frautschy, Jeffery Dean
Inman, Douglas L.
Nasu, Noriyuki
Parker, Frances L.
Revelle, Roger
Richards, Adrian F.
Scruton, Philip C.
Shepard, Francis P.
Long Beach—
Doane, George H.
Elliott, Wayne
Hurley, Myrl W.
Kuffel, George C.
Pierce, Richard L.
Rothwell, W. Thomas, Jr.
Sprotte, Edward C.
Los Angeles—
Arnal, Robert E.
Bandy, Orville L.
Chilingar, George V.
Clements, Thomas
Crawford, Frank Douglas
Easton, William H.
Emery, Kenneth O.
Goudkoff, Paul P.
Grant, U. S., IV
Hamill, James M.
Higgins, James W.
Hughes, Aden W.
Jones, Preston Douglas
Jurin, Nicholas V.
Laiming, Boris
Loel, Wayne
Mann, John F., Jr.
Melnikoff, Tikhon P.
Michelin, James
Parker, Frank S.
Pfeiffer, David H.
Rankin, Wilbur D.
Reed, Everett T.
Simon, Louis J.
Simonson, Russell R.
Thompson, Warren C.
Trapesonian, Gasaros M.
Weser, Oscar E.
White, William R.
Wissler, S. G.
Wong, Jackson
Menlo Park—
Rau, Weldon W.
Oakland—
Kleinpell, Robert M.
Oildale—
Morris, Robert Wynn
Ojai—
Armstrong, Ursel S.
Pacific Palisades—
Allison, Edwin C.
Traxler, J. Douglas
Palo Alto—
Driver, Herschel L.
Harrington, George L.
Meyerhoff, Arthur A.
Pasadena—
Israelsky, Merle C.
Lee, A. Theodore
Lowenstam, Heinz A.
Stauffer, Clinton R.
Weaver, Charles E.
Reseda—
Henderson, Nereida Mendoza
Rosemead—
Anderson, Howard T.
Rolling Hills—
Natland, M. L.
Sacramento—
Mills, John Howard
Salinas—
Tarbet, Loyal A.
San Diego—
Buffington, Edwin C.
Carsola, Alfred J.
Dietz, Robert S.
Hamilton, Edwin Lee
Menard, Henry W., Jr.
Moore, David G.
Russell, R. Dana
San Francisco—
Barbat, William F.
Church, Clifford C.
Hanna, G. Dallas
Weller, J. Marvin
Weymouth, A. Allen
Santa Barbara—
Norris, Robert M.
Santa Maria—
Turner, Francis E.
Stanford—
Graham, Joseph J.
Kelley, Frederic R.
Schenck, Hubert G.
Thalmann, Hans E.
Stockton—
Waldo, A. W.
Taft—
Lindblom, Robert Grant
Temple City—
Gilbert, Orrin W.
Van Nuys—
Slosson, James E.
Ventura—
Carson, Carlton M.
Conniff, John J.
Holzman, Johnston E.
Skolnick, Herbert
Smith, Bernice Young
Sturz, Charles E.
Whittier—
Braislin, Dana B., Jr.
Leith, Carlton J.
Riccio, Joseph F.
Woodland—
Pujol, Theodore J.

COLORADO

Boulder—
Chronic, John
Thompson, Warren O.
Toepelman, Walter C.
Denver—
Bass, N. Wood
Crowley, A. J.
Downs, George R.
Ellinwood, H. L.
Gilluly, James
McKee, Edwin D.
Mielenz, Richard C.
Rezak, Richard
Shelton, John W.
Taylor, Jane M.
Durango—
Bozanic, Dan N.
Elias, Gregory K.
Knight, Raymond L.
Golden—
Cathcart, James B.
Hayes, John R.
Johnson, J. Harlan
LeRoy, Leslie W.
Mateer, Warren D.
Grand Junction—
Cadigan, Robert A.
Robeck, Raymond C.
Weir, Gordon W.
Williams, George A.
Lafayette—
Moore, Fred E.

CONNECTICUT

East Haven—
Pickett, C. Rodman
Middletown—
Lehmann, Elroy Paul
New Haven—
Dunbar, Carl O.
Dunham, Robert J.

DISTRICT OF COLUMBIA

Washington—
Applin, Esther R.
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Bates, Charles C.

Boardman, Richard S.
Carroll, Dorothy
Chappars, Michael S.
Cobban, William A.
Cohee, George V.
Cooper, Chalmer L.
Finley, Emmett A.
Gardner, Julia
Gordon, MacKenzie, Jr.
Hawkins, Harold H.
Henbest, Lloyd G.
Knight, J. Brookes
Loeblich, Alfred R., Jr.
Manger, G. E.
Miser, Hugh D.
Nicol, David
Page, Lou Williams
Rubey, William W.
Schmidt, Ruth A. M.
Sohn, I. G.
Williams, James Steele
Wrather, W. E.

FLORIDA

Coral Gables—
Olsson, Axel A.
Fort Myers—
Campbell, Robert B.
Orlando—
Twenhofel, W. H.
Tallahassee—
Caldwell, Eleanor T.
Cheetham, Alan H.
Jordan, Louise
Puri, Harbans Singh
Raasch, Albert C., Jr.

GEORGIA

Marietta—
Johnson, Wendell B.

ILLINOIS

Champaign—
Brophy, John Allen
Cherry—
Kraye, Robert Frank
Chicago—
Cooley, Douglas R.
Eisenberg, Marvin
Emiliani, Cesare
Krinsley, David H.
Otto, George H.
Sangree, John B., Jr.
Seltin, Richard J.
Thomas, Norman L.
Winterbotham, John R., III
Effingham—
Bristol, Hubert M.
Evanston—
Dapples, Edward C.
Krumbein, William C.
Sloss, Laurence L.
Mattoon—
Henton, John M., Jr.
Mt. Vernon—
Brehm, Clarence E.
Olney—
Nuttall, Brandon
Salem—
Allison, James M.
Hockman, James N.
Skokie—
Stoever, Edward C., Jr.
Urbana—
Grim, Ralph E.
Hopkins, M. E.
Hough, Jack Luin
Johnson, Robert Britten
Major, C. Fred, Jr.
Scott, Harold W.
Shepps, Vincent C.
Siever, Raymond
Wanless, Harold R.
Wilson, George M.

INDIANA

Bloomington—
Galloway, J. J.
McGregor, Duncan J.
Murray, Haydn H.
Lafayette—
Serviss, Fred L.
Notre Dame—
Gutschick, Raymond C.

IOWA

Ames—
Hussey, Keith M.
Brandon—
Stainbrook, Merrill A.
Iowa City—
Miller, A. K.
Tester, Allen C.

KANSAS

Independence—
Studt, Charles W.
Lawrence—
DuBar, Jules R.
Fay, Robert O.
Frye, John C.
Hattin, Donald E.
Ireland, Hubert A.
King, Ralph H.
Merriam, Daniel Francis
Moore, Raymond C.
Pierson, J. R., Jr.
Swineford, Ada
Manhattan—
Byrne, Frank E.
Wichita—
Carmody, Robert A.
Koester, Edward A.
Travis, Richard
Walters, Robert F.

KENTUCKY

Hopkinsville—
Nosow, Edmund
Lexington—
Jacobsen, Lynn

LOUISIANA

Baton Rouge—
Camacho, Enrique
Howe, Henry V.
Murray, Grover E.
Tator, Benjamin A.
Harvey—
Smith, Denver J.
Lafayette—
Anderson, Irvin J.
Strachn, Clarence H., Jr.
Varvaro, Gasper Gus
Wiley, Richard A.
Lake Charles—
Beach, Paul R.
Chatham, E. Walter, Jr.
Latta, Lee Allen
Morrow, A. Lyndon
Munsey, Gordon C., Jr.
Tipsword, Howard Lee
New Orleans—
Akers, Wilburn H.
Braunstein, Jules
Clark, Robey H.
Everett, Robert W., Jr.
Morgan, Aylmer Lee, III
Slama, Don C.
Rayville—
Zingula, Richard Paul
Shreveport—
Brown, Dwight M.
Craver, Frank S., Jr.
Hazzard, Roy T.
Holden, Frederick T.
Moody, Clarence L.
Philpott, Thomas H.
Robinson, Van D.
Stone, Solon W.

MAINE

Millinocket—
Fairley, William M.
Orono—
Trefethen, Joseph M.

MARYLAND

Baltimore—
Pettijohn, F. J.
Bethesda—
Stephenson, Lloyd W.
Chevy Chase—
Ladd, Harry S.
Hyattsville—
Reeside, John B., Jr.
Kensington—
Dante, John Henry
Queenstown—
White, Maynard P.
Rockville—
McIntyre, John B.
Suitland—
Berninghausen, William H.

MASSACHUSETTS

Amherst—
Johansson, Warren Irving
Light, Mitchell A.
Sage, Nathaniel McLean, Jr.
Wilson, Leonard R.
Cambridge—
Barghoorn, Elso Sterrenberg
Kummel, Bernhard

Mencher, Ely
Moore, James Robert, III
Shrock, Robert R.
Stetson, Henry C.
Deerfield—
Rogers, Arthur A.
Northampton—
Shaub, Benjamin M.
Williamstown—
Ramsdell, Robert C.
Woods Hole—
Athearn, William Dean

MICHIGAN

Ann Arbor—
Briggs, Louis I., Jr.
Kellum, Lewis B.
Detroit—
Sanford, John T.
East Lansing—
Kelly, William A.

MINNESOTA

Minneapolis—
Goldich, Samuel S.
Kraft, John Christian
Sloan, Robert Evan
Swain, Fred M.
Northfield—
Stewart, Duncan
St. Paul—
Smith, William H.

MISSISSIPPI

Jackson—
Adams, Emmett R.
Anderson, Gerald K.
Brown, Charles E.
Coley, Tyrol B.
Karges, Harold E.
Martin, James L., Jr.
Mather, Katharine
Oglesby, W. R., Jr.
Parsons, W. Frank
Pike, Stuart J.
Laurel—
Hughes, Urban B.
University—
Hughes, R. J., Jr.
Shaver, Robert H.
Woodville—
West, Jesse W.

MISSOURI

Columbia—
Keller, W. D.
Peck, Raymond E.
Unklesbay, Athel G.
Ferguson—
Echols, Dorothy Jung
Kansas City—
Greene, Frank C.
Rolla—
Frizzell, Don L.
Higgs, William R.
St. Louis—
Brice, James Coble
Hinchey, Norman S.

MONTANA

Billings—
Beekly, Emerson K.
Darrow, George F.
Doroshenko, Jerry
O'Malley, F. Ward
Richards, Paul W.
Sonnenberg, Frank P.
Bonner—
Campbell, Charles V.
Great Falls—
Gribi, Edward A., Jr.
Wolf Point—
Peterson, John E.

NEBRASKA

Lincoln—
Elias, Maxim K.
Lugn, Alvin L.
Reed, Eugene C.

NEW HAMPSHIRE

Durham—
Gibson, Lee B.

NEW JERSEY

Emerson—
Klemme, H. Douglas
New Brunswick—
Fox, Steven K., Jr.
Martens, James H. C.
Nine, Ogden W., Jr.
Perth Amboy—
Sribny, Irene H.
Princeton—
Hess, Harry H.
Howell, B. F.
Van Houten, Franklyn B.

NEW MEXICO

Albuquerque—
Lovejoy, Bill P.
Thorp, Eldon M.
Wengerd, Sherman A.
Jal—
Taylor, Warren L.
Roswell—
McNulty, Charles Lee, Jr.
Meyer, Richard F.
Winkler, Hans
Socorro—
Teichert, Curt

NEW YORK

Bronxville—
Consiglio, Louis A.
Brooklyn—
Wang, Kia-Kang
Buffalo—
Hibbard, Raymond R.
Ithaca—
Palmer, Katherine V. W.
New York—
Eicher, Donald B.
Ellis, Brooks Fleming
Flagler, C. W.
Hull, J. P. D., Jr.
Imbrie, John
Jablonski, Eugene
Jaekel, Julie Anne
James, John W.
Kaufmann, Godfrey F.
Kay, Marshall
King, Robert Evans
Knebel, George Moses
Messina, Angelina R.
Newell, Norman D.
Salvador y Diaz, Amos
Sander, Nestor John
Sass, Louis Carl
Schaffel, Simon
Shields, James A.
Pittsford—
Alling, Harold L.
Poughkeepsie—
Johnsen, John H.
Warthin, A. S., Jr.
Rochester—
Davis, Stanley N.
Syracuse—
Apfel, Earl T.
Troy—
Beers, Roland F.
Lowman, Shepard W.

NORTH CAROLINA

Chapel Hill—
Griffin, George M.
Ingram, Roy L.
Powers, Maurice C.

NORTH DAKOTA

Bismarck—
DeLong, Jack M.
Harris, Steven H.
Scott, Edward W.
Fargo—
Pye, Willard D.
Tasch, Paul

OHIO

Athens—
Sturgeon, Myron T.
Cincinnati—
Abbott, Ralph E.
Caster, Kenneth E.
Holland, Frank D., Jr.
Columbus—
Bowen, Charles H.
Schopf, James M.
Spieker, Edmund M.
Stewart, Grace Anne
Summerson, Charles H.
Dayton—
Coryell, Horace N.
Oxford—
Martin, Wayne D.
Wade, F. Alton

OKLAHOMA

Ada—
Weiss, Hans
Ardmore—
Hicks, I. Curtis
Johnson, William R.

Neustadt, Walter, Jr.
Speer, John Hill
Tomlinson, Charles W.
Westheimer, Jerome Max
Wilson, Ruth B.

Bartlesville—
Strimple, H. L.
Weeks, Warren B.

Chickasha—
Bryan, J. Victor

Duncan—
Putman, Darrell M.

Enid—
Baker, Vernon R.
Clifton, R. L.
Douglass, Harry Marvin
Muir, J. Lawrence

Muskogee—
Wallace, Maurice H.

Norman—
Branson, Carl C.
Culp, Eugene F.
Decker, Charles E.
Frederickson, Edward A.
Harris, Reginald W.
Huffman, George G.
Lucas, Elmer Lawrence
Moore, Carl A.
Tanner, William F.

Oklahoma City—
Batchelor, Jo Wolter
Blythe, Jack Gordon
Eisner, Stephan M.
Gibson, William C.
Isbell, Grover Jim
Kate, Frederick H.
McGee, Dean A.
Pasquella, George G.
Pollard, Robert T.
Tubb, George G.
Turk, Lon B.

Shawnee—
Phillips, David L.

Tulsa—
Andrichuk, John Michael
Bennison, Allan P.
Bramlette, W. A.
Branson, Herberta Van Pelt
Brown, Alfred L.
Connolly, Frank T.
Denison, A. Rodger
Ellsworth, Elmer W.
Enlows, Harold E.
Goldstein, August, Jr.
Grigsby, R. B.
Harlton, Bruce H.
Hawkins, Glenn D.
Kauffman, James S.
Kjellesvig-Waering, Erik N.
Levorsen, A. I.
Porterfield, Robert R.
Reeves, James E.
Rittenhouse, Gordon
Ryniker, Charles
Snider, James W.
Steele, Grant
Vernon, Roger C.
Wagner, Carl D.

OREGON

Corvallis—
Boyd, Harold A., Jr.

Eugene—
Baldwin, Ewart M.
Bressler, Calder T.

Portland—
Hoover, Linn
Stewart, Roscoe Emerson

PENNSYLVANIA

Bethlehem—
Willard, Bradford

Bird-in-Hand—
Moss, John Hall

Philadelphia—
Weeks, H. J.

Pittsburgh—
Cox, Ben B.
Fettke, Charles R.
Hedberg, Hollis D.
Lattman, Laurence H.
Sutton, A. H.

Rochester—
Wozab, David H.

State College—
Cochran, John A.
Emery, John R.
Griffiths, J. C.
Kahn, J. Steven
Krynine, Paul D.
Swartz, Frank M.

RHODE ISLAND

Kingston—
Donohue, John J.
Garrison, Louis Eldred
McMaster, Robert L.

SOUTH DAKOTA

Rapid City—
Tullis, Edward L.

Vermillion—
Stevenson, Robert Evans

TEXAS

Abilene—
Conselman, Frank B.
Fountain, H. C.
Morrison, Robert E.
Weart, Richard C.
Zimmerman, Donald A.

Amarillo—
Britt, Harry M., Jr.
Buck, Charles E.
Lohman, Clarence, Jr.
Reiter, Frederick H.
Tarver, Jack H.

Austin—
Amsbury, David L.
Barnes, Virgil E.
Bell, W. Charles
Damon, H. Gordon
Eargle, D. Hoye
Ellison, Samuel P., Jr.
Folk, Robert L.
Grant, Richard E.
Gurel, Mehmet
Horton, Claude W.
Jeffords, Russell M.
Lonsdale, John T.
Morey, Philip S.
Pittman, James S., Jr.
Stenzel, H. B.
Twining, John T.
Whitney, F. L.
Wimberley, C. Stanley
Young, Keith P.

Bellaire—
Caldwell, Barbara Summerill
Holliday, Samuel
Setzer, Francis M.

Beaumont—
Eveland, Harmon E.

College Station—
Dunlap, John B., Jr.
Gimbrede, Louis de A.
Lynch, Shirley A.
Smith, Fred E.

Corpus Christi—
Cook, Theodore D.
Holcomb, Charles W.
Owens, Frith Cravens
Theessen, E. J.
Williams, Harry F.

Dallas—
Albritton, Claude C., Jr.
Alexander, C. I.
Alexander, W. H., Jr.,
Billingsley, Harold Ray
Bradfield, Herbert H.
Brooks, James Elwood
Clark, John W.
DeGolyer, E.
Feray, Dan Edwards
Grubbs, David M.
Hamilton, I. B.
MacNaughton, Lewis W.
Moreman, Walter L.
Perkins, Bob F.
Renfro, Kenneth M.
Sellin, H. A.
Taylor, Jack A.
Thompson, S. A.
Waters, James A.

El Paso—
Baldwin, Don C.
Nelson, Lloyd A.

Fort Worth—
Donoghue, David
Harges, Marvin E.
Hendricks, Leo
King, William Edward
McBride, Mary Wood
Schweers, Richard Henry
Stewart, Wendell J.
Upson, M. E.
Winton, W. M.

Gorman—
Brogdon, Dewey Robert

Houston—
Albers, Charles C.

Baker, William A., Jr.
Bane, M. Ray
Bannahan, Annabelle
Barker, R. Wright
Bell, Olin G.
Bernard, Hugh A.
Bokman, John Willard
Bradley, John S.
Bright, Anna Lou
Brixey, Austin Day, Jr.
Brockhouse, Robert B.
Bush, James
Campbell, Curran R.
Carstens, Fred D.
Colle, Jack O.
Contreras, Carlos E.
Cotton, Edgar A.
Cram, Ira H.
Croneis, Carey
Crouch, Robert W.
Cruse, John S., Jr.
Denham, Richard L.
Deussen, Alexander
Ellis, Albert D., Jr.
Fan, Paul H.
Ferguson, H. C.
Fisk, Harold N.
Garrett, J. B., Jr.
Gilkison, Dwight C.
Goodrich, Paul K.
Halbouty, M. T.
Halsted, Morris E.
Hanna, Marcus A.
Hodges, Clifford H.
Hornberger, Joseph, Jr.
Ikins, William C.
Kilgore, John E.
Kirby, Louie C.
Koenig, Karl J.
LeBlanc, Rufus J.
Levinson, Stuart A.
Ludwick, John C.
Malicoat, Arthur F.
Martyn, Phil F.
Masson, Peter H.
McFarlan, Edward, Jr.
Montgomery, J. C.
Moore, Jean M.
Morrison, T. E.
Nanz, Robert H., Jr.
Nelson, Paul Hugh
Nygren, Walter Eric
Overton, Charles K.
Parker, William G.
Parks, James M., Jr.
Payne, Thomas G.
Petrusek, Benjamin J.
Phillips, Henry H.
Pyeatt, Lloyd M.
Quigley, Claude M., Jr.
Reiter, W. A.
Roederer, Edward P., Jr.
Rolshausen, F. W.
Sawin, Horace J.
Selig, A. L.
Smith, Fred L., Jr.
Speed, Carleton D., Jr.
Stephenson, Morton B.
Stevenson, Frank V.
Stubbs, Sidney A.
Stuckey, Charles W., Jr.
Sutherland, Patrick K.
Tatum, Emmett P.
Towbridge, A. C.
Walk, Hugh G.
Walter, Joe C., Jr.
West, Glen D.
Westmoreland, Frank S.
Whipple, G. Leslie
Wilson, James Lee
Woods, Raymond D.

La Pryor—
Grant, Drane Fones

Lubbock—
Arper, William B., Jr.
Brand, John Paul
Sidwell, Raymond

McAllen—
Lalicker, Cecil G.
Means, John A.

Midland—
Adams, John Emery
Adent, William A.
Arick, Millard B.
Clarkson, William G., Jr.
Ewbank, Norman Ware, Jr.
Frenzel, Hugh N.
Hollingsworth, R. V.
Kerr, S. Duff, Jr.
Mills, Lloyd C.
Montgomery, James H.
Rothrock, Howard E.
Scobey, Ellis H.
Skinner, John W.
Spencer, Maria
Stead, Frederick L.
Toomey, Donald F.
Wilde, Garner Lee
Williams, Harold L.
Wimbish, Forrest Edwin

San Angelo—
Roper, Frank C.

San Antonio—
Grasso, Volker C.
Krause, Erwin Koerps
Magaw, Mary Catherine
Owen, Edgar W.
Petty, Dabney E.
Ritts, L. Chase, Jr.
Rogers, James K.
Sandidge, John R.
Scrafford, J. Bruce
Siemer, William J.
Still, J. T.
Tartamella, Natale John

Seguin—
Kniker, Hedwig T.

Seymour—
Kemp, Augusta Hasslock

Tyler—
Bunch, Rosella L.
Hurlbut, Elvin M., Jr.
Peters, Theodore C.

Wichita Falls—
Drake, Robert T.
Osmond, John C., Jr.
Richards, David T.

Utah

Salt Lake City—
Barkell, Clifford A.
Darrow, Richard Lee
Jones, Daniel J.
Peterson, James A.

Virginia

Alexandria—
Goldman, Marcus I.
McLean, James D., Jr.

Charlottesville—
Young, Robert S.

Falls Church—
Palmer, Allison Ralph

Lexington—
Stow, Marcellus H.

New Market—
Herbert, Paul, Jr.

Washington

Montesano—
Riveroll, David D.

Pullman—
Scott, W. Frank

Raymond—
Kirsch, M. Ivo, Jr.

Seattle—
Coombs, Howard A.
Danner, Wilbert R.
Fulmer, Charles V.
Gould, Howard R.
Mallory, V. Standish
Wheeler, Harry E.

Spokane—
Freeman, Val LeRoy

West Virginia

Clarksburg—
Bayles, Robert E.

Huntington—
Sprouse, Donald W.

Morgantown—
Heald, Milton T.

Wisconsin

Green Bay—
Riggs, Elliott A.

Madison—
Bebout, Don Gray
Bostwick, David A.
Gehrig, John Leonard
Hill, John Davis
Moore, Walter L.
Sanderson, George A., Jr.
Thompson, M. L.
Tyler, Stanley A.
Van Sant, Jan F.
Zeller, Edward J.

Menasha—
Hecht, Richard J.

Platteville—
Agnew, Allen F.

WYOMING

Basin—
Lease, Leslie W.
Casper—
Chamney, T. Potter
Dresser, Hugh
Greenman, Norman N.
Haertlein, James Allen
Munyan, Arthur C.
Reinhart, Philip W.
Swirczynski, Richard Paul
Worland—
Hanson, Alvin M.

OUTSIDE THE UNITED STATES

ALBERTA

Calgary—
Atkinson, Eric
Burgers, Willem
Chakravorty, Sailendra K.
Chilton, Mertie Ann
Crombie, Gordon Peers
Erickson, Robert H.
Fong, George
Goodman, A. J.
Hilgers, C. L. L.
Hunt, C. Warren
MacKay, Ian H.
Moore, Peter F.
Raasch, Gilbert O.
Rands, Claud N.
Renaud, Jacques E.
Sproule, J. C.
Wegmuller, Walter
Wickenden, Robert T. D.
Williams, Edwin Philp
Wonfor, John S.
Workman, Lewis E.

ALGERIA

Alger—
Dunand, Georgette
Magne, Jean
Termier, Henri

AUSTRALIA

Adelaide—
Glaessner, Martin Fritz
Boronia—
Nadeau, Betty Kellett
Canberra—
Crespin, Irene
Sydney—
Browne, Ida A.

AUSTRIA

Vienna—
Schors, W. W. L.

BARBADOS

Bridgetown—
Ronai, Peter H.

BELGIAN CONGO

Leopoldville—
Zimmermann, Fritz R.

BELGIUM

Brussels—
Brognon, Georges P. G.
Lombard, Augustin E.
Gand—
Tavernier, R.
Liege—
Calembert, Leon M. C.
Ubaghs, Georges J. C.
Louvain—
Gullentops, Frank B.

BRAZIL

Bahia—
Brantly, John E., Jr.
Curitiba—
Salamuni, Riad
Rio de Janeiro—
Yenne, Keith A.

BRITISH COLUMBIA

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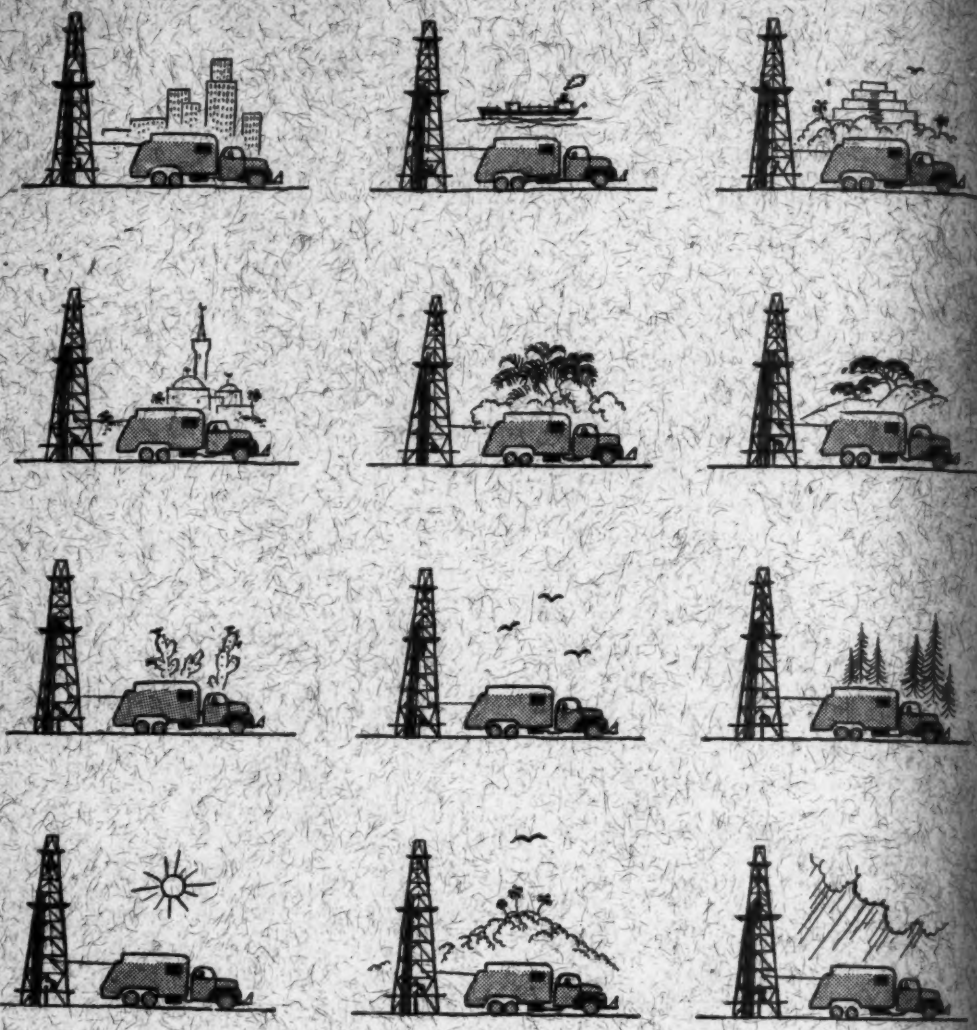

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